# ENGINEERING MATERIALS

## AS USED IN INDIA

## THEIR NATURE, PRODUCTION AND USE

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To

The Revered Memory

of

My Parents

# PREFACE TO THE FIRST EDITION

In India there is a dearth of well-arranged text books on Engineering Materials as used in India to meet the needs of the average Indian students. Some text books on the subject are so condensed that they do not give a fair idea of the subject but tend to encourage the pernicious practice of cramming; others are so elaborate that they may be used for reference purposes only, as engineering students and young engineers have not enough time to spare for them. Again in some books no reference is made about weight, strength, cost and manufacture. In this volume pre-war rates are used as the present rates are fluctuating.

In writing the present work the author has in view chiefly the needs of engineering students, practising young engineers, architects and builders in India desirous of obtaining some knowledge of the nature, characteristics, qualities, defects, testing, strength, cost and the manufacture of Engineering Materials as used in India. The book is concise, well-arranged, fully illustrated in one volume to suit all pockets and is written in a language so simple that any student with only a fair knowledge of engineering can easily follow it. Special care has been taken to explain what is found to be common difficulties with beginners.

Many useful information have been given in chapter seven and some tables and specifications have also been added which builders and contractors of houses will find very convenient and useful. For the convenience of engineering students, questions have been added at the end of each chapter and some examination papers on the subject of the Calcutta and Patna Universities have been added at the end of the book with the permission of the authorities concerned. With this book in hand, Indian students can look upon engineering studies on the subject as a matter of pleasure rather than drudgery.

In class rooms notes can easily be amplified by explanations or exhibition of models. Engineering students should improve their power of observations by minutely looking into all constructions they will come across and taking notes and sketches of parts new to them instead of looking at things indifferently.

Many books on the subject have been referred to and consulted in the preparation of this work. To all and each of them the author's hearty thanks are due. Much assistance has been afforded in preparing diagrams by some students of A.S.E., Dacca, to whom the author conveys his sincere thanks. The author takes this opportunity of thanking the universities concerned and other friends who have given suggestions for the improvement of the book.

The author will be amply recompensed for his long and hard labour if readers especially the engineering students in India find the book sufficiently useful for their purpose.

The book has been hurried through the press and hence there may be some mistakes or misprints. The author will thankfully receive suggestion for improvement from professional gentlemen or educationists who may come across errors in the book.

Dacca, August 1944 **K.P. Roy Chowdhury**

# CONTENTS

**Chapter 1. Stones** ... 1

Choice of Stones, Formation of Rock, Classification, Composition, Uses, Characteristics, Test and Examination, Preservation, Quarrying, Dressing, Sawing and Polishing, Commonly Used Stones, Classification of Sandstone, Classification of Limestone, Slates, Artificial or Cast Stones, Classification, Reconstructed Stone, Bituminous Stone, Fire and Electrical Resistance by Stones, Precautions, Specifications, Stone Quarries in India.

**Chapter 2. Bricks, Tiles, Terra Cotta, Etc.** ... 31

Introduction, Bricks, Composition, Properties, Practical Classification, Analysis, Test of Clay, Brick Making, Sizes and Weights, Classification, Characteristics, Uses, Strength, Quality, Special Forms, Classification According to Moulding, Fireclay and Firebricks, Strength of Refractory Bricks, Colour, Tiles, Manufacture of Flat Tiles, Structural Hollow Clay Tiles, Efflorescence in Brickwork and Remedial Measures, Earthenware and Stoneware, Terra Cotta and other Claywares, Porcelain, Testing of Bricks, Tiles.

**Chapter 3. Lime, Cement, Mortar, Concrete, Etc.** ... 83

Sources of Lime, Varieties, Explanation of Terms, Constituents, Classification, Comparison, Characteristics, Tests, Uses, Cement, Sand, Surki, Mortar, Plaster, Gypsum Plasters, Concrete, Grading of Aggregate, Sieve Analysis, Proportion of Ingredients, Mixing, Laying, Joints in Concrete, Finishing Concrete or R.C. Surface, Strength of Concrete, Uses, Methods, Red Cement, Aerated Concrete, Vibrated Concrete, Precast Concrete, Vaccum Concrete, Water-Cement Ratio, Curing Concrete, Faulty Concrete, Ferro Concrete.

**Chapter 4. Timber** ... 162

Definition, Growth of Trees, Time for Felling, Defects in Timber, Characteristics, Seasoning, Diseases, Preservation, Classification, Market Forms of Timber, Measurement, Plywoods, Bamboo.

**Chapter 5. Metal and Alloys** ... 193

Metallurgy, Iron, Steel, Modern Alloy Steel, Rolling, Forging and Drawing, Market Forms of Steel and Wrought Iron, Stainless Steel, Non-ferrous Metals, Alloys.

**Chapter 6. Paints and Varnishes** ... 248

Paint, Classification, Constituents, Characteristics, Painting, Faults, Ingredients, Varnish, Polishes, Characteristics, Application.

**Chapter 7. Miscellaneous** ... 267

Glass, Resins, Glue, Putty, Petroleum, Bitumen, and Asphalt, Asphaltic Cement, Fuels, Tar and its Products, Turpentine, Knotting, Cellulose, Wall and Ceiling Papers, Paste, Asbestos, Fibres and Felt, Rust Cement or Cast Iron Cement, Abrasives, Emery Cloth and Emery Paper, Lath, Cork Products, Gasket, Rubber, Belts, Gutta-percha, Mica, Plastics, Gold Leaf, Ropes, Nails, Screws, Bolts and Rivets, Water, Hume Pipe, Lubricants, Refractories, Heat Insnlators, Sound Insulators, Electrical Goods.

**Appendix I.** Weights and Strength of Materials ... 315

**Appendix II.** British Standard Specification for Structural Steel for Buildings and Bridges ... 316

**Appendix III.** Approximate Rates of Materials ... 317

**Appendix IV.** Subjects of Studentship and Associated Membership Examinations of the Institution of Engineers (India) ... 318

**Appendix V.** A.M.I.E (Ind.) Examination Syllabus on Engineering Materials ... 319

**Index** ... 329

# ABBREVIATIONS

R. B.—Reinforced Brick
R. C.—Reinforced Concrete
R. B. C.—Reinforced Brick Concrete
R. B. L. C.—Reinforced Brick Lime Concrete
C. I.—Cast Iron
H. S.—Hard Steel
M. S.—Mild Steel
W. I.—Wrought Iron
Ag—Silver
Al—Aluminium
Cu—Copper
Pb—Lead
Sn—Tin
Zn—Zinc

Be—Beryllium
Cr—Chromium
Co—Cobalt
Ir—Iridium
Mn—Manganese
Mo—Molybdenum
Ni—Nickel
Os—Osmium
W—Tungsten
V—Vanadium

M. S. J.—Mild Steel Joist
R. S. J.—Rolled Steel Joist
B. W. G.—Birmingham Wire Gauge
S. W. G.—Standard Wire Gauge
C. I. Sheet—Corrugated Iron Sheet
I. Section—Joist Section
L Iron—Angle Iron
T Iron—Tee Iron
P. W. D.—Public Works Dept.
Ry.—Railway
B. S. S.—British Standard Specification
I. S. S.—Indian Standard Specification

## DON'TS FOR BEGINNERS

1. Don't try to commit to memory the subject without understanding it and thereby you may answer one thing for the other. Better go deep into the subject, try to remember engineering terms and points only and then you will be in a position to answer correctly at any time.

2. Don't forget to learn the spellings of the names of engineering materials as used in India. You won't be excused for giving wrong spellings for them as slips of pen. Concrete is sometimes carelessly written as konkrit, conkrit, koncrete, etc.

3. Don't answer before you think. Your answer must be to the point otherwise you won't get any credit for your careless answer.

4. Don't be frightened at the first sight of the question but study it thoroughly cool headed and then you will find it not so difficult as you have thought.

5. Don't try to answer all the questions without revisions. It is always better to answer a few questions correctly rather than answering the whole lot incorrectly or carelessly.

6. Don't give a long description of appliances but draw neat sketches showing the different parts with necessary dimensions wherever possible. Remember that drawing is Engineer's language.

7. Don't mix up with Metric and British Units.

8. Don't be untidy and unmethodical in your words, figures and sketches.

# Chapter 1

## STONES

### 1.1 Choice of stones

Stone, which is obtained from natural rock, is most durable and least expensive of all materials of construction so far as upkeep is concerned when properly chosen to suit climatic conditions. Sometimes choice is limited to stone quarried locally when the cost of transport is very heavy.

The quality of the stone available however requires examination in respect of the characteristics described in paragraph 1.6 of this chapter.

### 1.2 Formation of rock

The solar system consists of the sun at the centre and many planets revolving round it with their satellites. According to Laplace's theory the solar system originally existed as a revolving mass of incandescent gas. This fire cloud revolved in space, gradually cooled commencing from the surface. It continued to loose its heat and so one after another different planets, of which our earth is one, condensed into a molten mass from the vapour cloud and ceased to be luminous. The process of cooling still continued and in course of time our globe of molten matter was covered with a solid crust of skin. Due to further contraction it was subjected to alternate upheaval and depression while the crust was thin and thereby raised some parts producing hills and plains and depressed others to form lakes, seas and oceans. These forces are still going on, but movements are hardly perceptible as the crust is very thick now. Other chief causes of the unevenness are due to earthquakes, volcanic eruptions and wearing away of the surface by the action of water, wind, frost, etc. Molten matter or lava, coming out from the uncooled interior of the earth during volcanic eruptions, cooling and solidifying after reaching the surface of earth, is *igneous rock*. The deposition of broken up materials in the shape of sand, clay and pebbles, formed due to the weathering action of earth's crust by atmospheric action, carried by running water and settled down when velocity gets less, for ages in layers or beds to the bottom of sea or lake where in course of time they solidify and appear on the surface either by draining off the water or by upheaval of the bed. Materials so deposited, pressed and hardened by the weight of deposits above and mixed with natural cementing material, form *sedimentary rock*. Rock not distinguishable as regards its formation is called *metamorphic rock*.

## 1.3 Classification of stones

1.3.1 *Geological classification*—Stones are classified under three main heads based on geological formation.

1.3.1.1 *Igneous, Eructive or Unstratified*—Formed by the solidification of molten material which was in a state of fusion and is of volcanic origin. The structural feature of such rocks depends upon the manner of its solidification and composition of the constituent materials. They are generally strong, durable, massive and crystalline. Examples are granite, trap and basalt. Granite has large crystals as it is formed due to slow cooling of lava. The thick covering of earth crust at the top is responsible for the slow cooling. In case of trap and basalt, the rate of cooling is quicker as they are formed at the surface of the earth. As a result of this they are non-crystalline, amorphous and glassy in texture. Figure 1.1 explains the formation of igneous rocks.

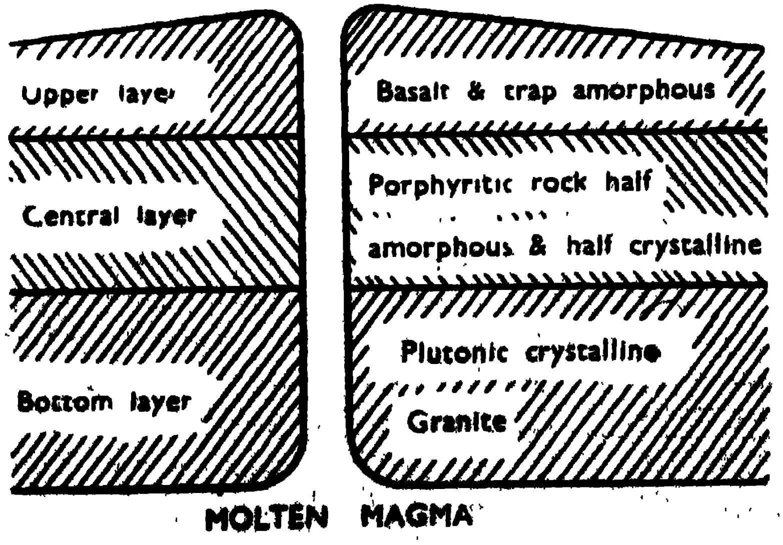


Fig. 1.1 Formation of igneous rocks

**1.3.1.2** *Sedimentary, Aqueous or Stratified*—It is gradually deposited in layers and formed by the action of air or water ; such as, limestone, sandstone and slate.

The deposition of suspended particles is responsible for the formation of most of the sedimentary rocks. Some times erosion of the primary rock and its subsequent sedimentation gives rise to sedimentary rocks. The formation of these rocks is explained in Fig. 1.2.

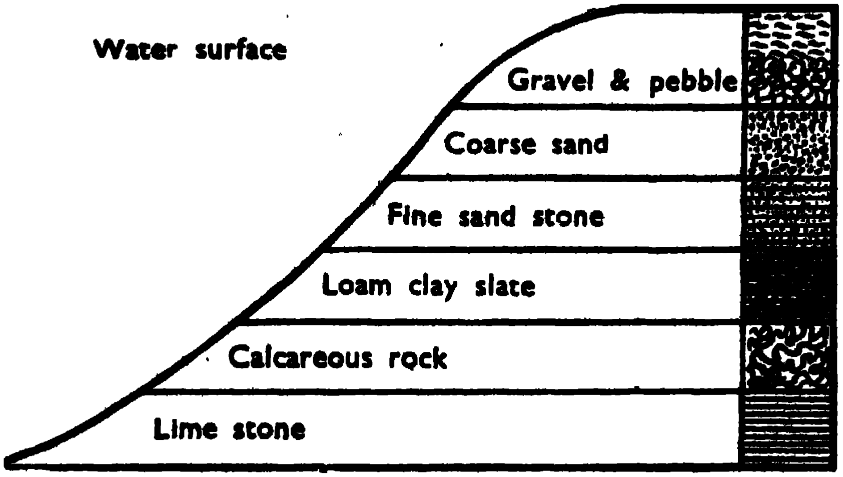


Fig. 1.2 Formation of Sedimentary Rock.

**1.3.1.3** *Metamorphic, Altered or Foliated*—It is either of the abo classes with alteration in form caused by great heat, pressure or botl such as, clay, slate, marble, dolomite and gneiss.

"Thermo", "dynamo" or "hydro" metamorphosis is responsib

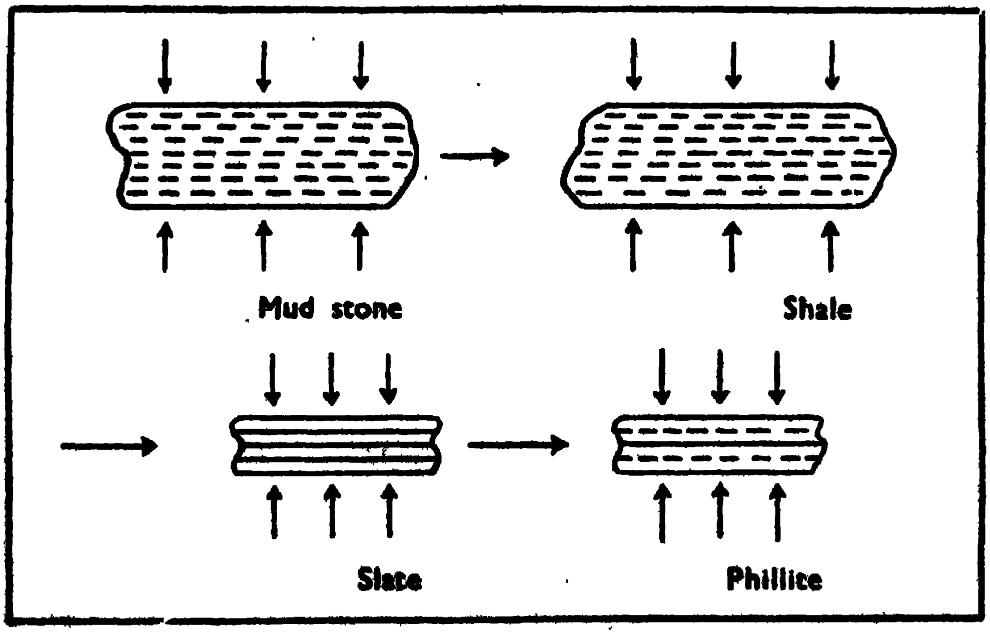


Fig. 1.3 Formation of Metamorphic Rock.

for their formation. As a result of metamorphosis, limestone and marl become marble, basalt and trap become chist and laterite and granite becomes gneiss. The conversion of stone is explained in Fig. 1.3. It shows how mud stone gets converted into slate. Due to compression new planes of stratification are formed.

1.3.2 *Engineering or Scientific Classification*—Stones for engineering works are divided into three classes by Engineers based on chemical composition.

1.3.2.1 *Silicious*—Its principal constituent is silica; such as, granite, syenite, serpentine, gneiss, trap, basalt, quartzite and sandstone.

It is unaffected by weathering action and is very hard and durable. The presence of weaker materials however causes its disintegration.

1.3.2.2 *Argillaceous or clayey*—Its principal constituent is clay; such as, porphyry, laterite and clay slate.

The chief constituent is alumina mixed with varying proportions of silicious, calcareous and carboneous matter. They are brittle but hard and durable.

1.3.2.3 *Calcareous*—Its principal constituent is carbonate of lime; such as, limestone, dolomite, marble, kankar and gravel.

1.3.3 *Practical Classification*—Stones are classified under four heads to suit the practical needs of the users of stones based on physical characteristics:

1. *Granite and other igneous stone*
2. *Slate and schist*
3. *Sandstone*
4. *Limestone.*

## 1.4 Composition of stones

Chemically stones are composed of the following principal constituents:

Mineral Earths:—Silica ($SiO_2$), Alumina ($Al_2O_3$), Lime ($CaO$), Magnesia ($MgO$).

Alkalies:—Soda ($Na_2O$), Potash ($K_2O$).

There are also small percentage of oxides of iron and manganese. Alkalies cause stone to disintegrate when exposed to weather.

Physically stones are composed of one or more of the above mineral earths held mechanically by cementing material.

Common materials constituting the stones are given below :

1.4.1 *Quartz* ($SiO_2$)—Certain varieties of gneiss, granite and sand stone contain large proportion of silica. Various metallic oxides impart various colour shades to otherwise normally white coloured stone. Flint, chalcedony, agate, are the various forms of coloured quartz. Pure quartz is crystalline and translucence. Its specific gravity is 2.6 and hardness 7.

1.4.2 *Felspar* ($K_2O.\ Al_2O_3.\ 6\ SiO_2$)—All igneous rocks have felspar as an important mineral. The red colour is imparted by a small quantity of iron oxides. It may be aluminium silicate with sodium or potassium silicate or both. When potassium is present it is fresh coloured and is known as orthoclase.

1.4.3 *Mica*—It occurs in the form of their laminated transparent plates along which it readily splits. Its flakes have metallic lustre. Its presence causes quick degeneration of the stone. Its specific gravity varies between 2.7 and 3.2 and hardness from 2 to 3.

1.4.4 *Hornblende* [$5\ (Ca\ Mg).\ 6\ SiO_2$]—Very strong and durable mineral being brown, black or darkgreen in colour. It is however brittle. Its specific gravity vane from 2.9 to 3 and hardness from 5 to 6.

1.4.5 *Augite* ($(Ca,\ Mg).\ SiO_2$)—It is similar to hornblende but is heavier as the specific gravity goes upto 3.6 against 3 of hornblende. It is found in abundance in Deccan trap.

1.4.6 *Calcium Carbonate*—It is the main constituent of limestone, chalk and calcareous stones and occurs in sand stone and shale as cementing material.

### 1.5 Uses of stones

Blocks of stones are used generally in all situations where strength and durability are taken into consideration, such as, foundations, walls, bridge piers and abutments, light houses, aquaducts, retaining walls, etc. Broken stones are used as aggregate in concrete, road metal, railway ballast, etc.

Flags or thin slabs are used for paving, slates for roofing tiles, limestone for manufacture of lime and flux in blast furnaces, and murum for covering road surface (blindage).

.It is a natural substitute for natural sand and for manufacture of artificial stones and hollow and solid blocks in its crushed form.

In the manufacture of lime and calcareous cements, lime stone is the basic material.

Stone is used as murum for roads, floors and floor fillings in its disintegrated form.

### 1.6 Characteristics of good stones

In selecting a stone for an engineering work, the following characteristics should be looked into though the choice is in most cases further limited by the cost.

Other things being equal, its cost depends upon the ease with which it could be quarried out, the proximity of the quarry to the place of use, and transport facilities available.

**1.6.1** *General Structure*—Structure may primarily be unsatisfied (granular), foliated or stratified.

**1.6.1.1** Rocks of igneous origin have unstratified structure. Depending upon the time of cooling they are crystalline or amorphous. They are good for building stones.

**1.6.1.2** Materials from the disintegration of originally formed rocks form stratified rocks. Their layers of stratification are interposed by their laminae. The planes of stratification provide a plane for ready splitting.

**1.6.1.3** Metamorphic rocks have foliated structure. In this case the layers of stratification are not formed due to deposition but due to metamorphic action of heat and pressure and hence these layers are not uniform.

**1.6.2** *Fineness of Grain*—Fine-grained stones are most suitable for carved and moulding works. Stones are liable to be disintegrated if the particles are non-crystalline or amorphous.

**1.6.3** *Compactness*—Compact stones are durable in general. So best stones are those of older formations found at a great depth and subjected to the pressure of earth above. Sometimes these are brought to the surface due to the earthquakes or volcanic eruptions.

**1.6.4** *Porosity and Absorption*—All stones are porous but some stones are so porous that they are most unsuitable for exposed situation. Porous stones are destroyed by decomposition or disintegration or both combined. Stones are tested by soaking specimens in water and noting the amount of water absorbed.

The mineral constituent of the rock gives the property of absorption where as porosity depends upon the void space between the minerals and the way in which they are grouped.

Porosity is empressed in terms of absorption of water with the dry weight of stone. Clay and porous varieties may have as high porosity as 7 percent by weight where as compact stones may have negligible.

1.6.5 *Durability*—The durability of a stone depends on its chemical composition and physical structure and also its position in the building. Stones, which are crystalline in structure, homogeneous and close grained with good cementing material, have a power to resist wear and tear due to atmospheric and other causes.

1.6.6 *Strength*—Strength need not be considered for ordinary building works but it is to be taken into consideration when the stone is subjected to excessive stress. The resistance to crushing of stones ranges from 150 to 1000 kg/cm$^2$.

Whereas the weakest variety of stone is quite safe for residential buildings, for example the maximum compressive stress in a three storey residential building would be only 4.5 kg/cm$^2$. In the case of structures like dams, retaining walls, major bridges etc. however, the stresses developed may be considerable and it should be ensured that this does not exceed one tenth of the crushing strength of the stone.

1.6.7 *Hardness*—Hardness is to be taken into consideration when it is subjected to a considerable amount of wear and friction as in the case of floors and pavements. A scrach with fingure nail indicates a hardness of H=2. Hardness of limestone may be taken as H=3. Silicious rock not scratched by knife represents a hardness of H=7. Hardness is determined by Mohr's scale of Hardness.

1.6.8 *Weight*—It is to be taken into consideration especially in marine engineering works. Heavy stones are required for dams, retaining walls, etc. to add to their stability while for arches, vaulting, etc. light stones are to be preferred. Weight ranges from 1,200 to 2,800 kg/m$^3$.

1.6.9 *Appearance*—This point is important for the face work of buildings for their architectural beauty. Durable stones, uniform in colour and structure, are used in order to keep up the appearance of a building.

Harder varieties of crystalline stone having a dense structure are preferred for facework of important buildings as they take fine polish. Slate, marble, granite and compact varieties of lime stone take up polish well.

**1.6.10** *Facility for Working*—The ease with which stone can be cut or dressed into different shapes and sizes is an important consideration from economical point of view.

It is easy to dress soft as well as freshly quarried stone.

**1.6.11** *Seasoning*—Stones just after quarrying contain moisture called *quarry sap*, which makes those soft and easier to cut. So the stones should be dressed soon after quarrying. It is important that the sap should be expelled before their use in constructional works otherwise stones will disintegrate. After quarrying, stones are seasoned in open air, say for six to twelve months, so as to be acted upon by the sun and wind. These are often covered on the top to protect them from rain.

**1.6.12** *Natural Bed*—Natural beds in stones are planes of stratification formed by successive layers of deposit by running water and having reduced cohesion. It is not always horizontal, the strata being often inclined due to the disturbances of volcanic or other agencies. In walls all stratified stones should be placed on their natural bed i.e. in the same position in which they were originally deposited. The natural bed of stone should be at right angle to the pressure so as to get maximum strength to resist crushing. Stones are placed with layers at right angle to the face of the wall so as to offer greatest resistance to disintegration by frost or other sources. In arches, the bedding plane should be radial and at right angles to the face of the arch, so that they will be at right angles to the line of thrust of the arch. In string courses and cornices the natural bed has to be kept vertical. In Fig. 1.4 (*a*) and (*b*) the correct and incorrect positions of stones are shown.

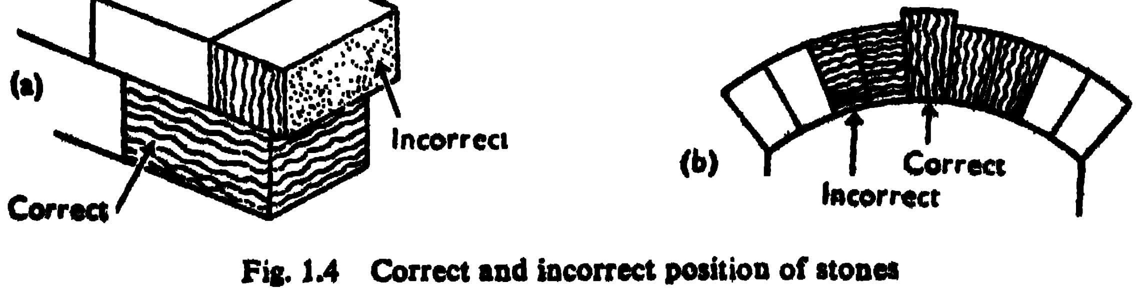


Fig. 1.4 Correct and incorrect position of stones

The natural bed is seen in some cases of stones by the position of imbedded shells which were originally deposited but in other cases it can be traced out by the traces of laminae prominent when stones are wet. A good mason can find out easily the natural bed of stone by the 'feel' of the grains in working the surface.

1.6.13 *Weathering*—It is the power to resist the action of weather i.e. wear and tear due to atmospheric causes. Good weathering stones should be selected for face work in order that the previous appearance may be maintained.

## 1.7 Test and examination of stones

Generally in ordinary atmosphere least porous, densest and strongest stone will be most durable. The following tests may be applied to find out the suitability of stones for building purposes.

1.7.1 *Smith's Test*—Put a few small chips from a freshly quarried stone into a glass one-third full of water and then stir briskly for half an hour. Stone will not be durable if the water becomes dirty.

1.7.2 *Brard's Test*—Weigh a few stone chips when damp and then immerse those in a concentrated boiling solution of sulphate of soda. The stone is suspended for a few days and reweighed. The loss in weight shows the probable effect of frost.

1.7.3 *Acid Test*—This test is performed to assess the contamination due to the exposure of the stone on account of its exposure to industrial atmosphere charged with acid fumes for stones other than lime stone. About 50 gms sample of stone is immersed in 1% hydrochloric solution for 7 days. If the sharpness of edges and corners is maintained at the end of this period, it is assumed to possess satisfaction weathering properties.

1.7.4 *Resistance to Crushing*—In ordinary building work the pressure normally does not exceed 10 kg/cm$^2$ where as the crushing strength of stone varies from 150 to 1000 kg/cm$^2$. This factor therefore need not be considered for ordinary building work, however if required, the strength can be tested in a compression testing machine.

1.7.5 *Weathering Qualities of Stone*—Examine the faces of new quarried stone and old buildings made of that stone.

1.7.6 *Absorption Test*—To get the weight of dry specimen, 50 gms of specimen are placed in an oven at 105°C for 72 hours and cooled in a

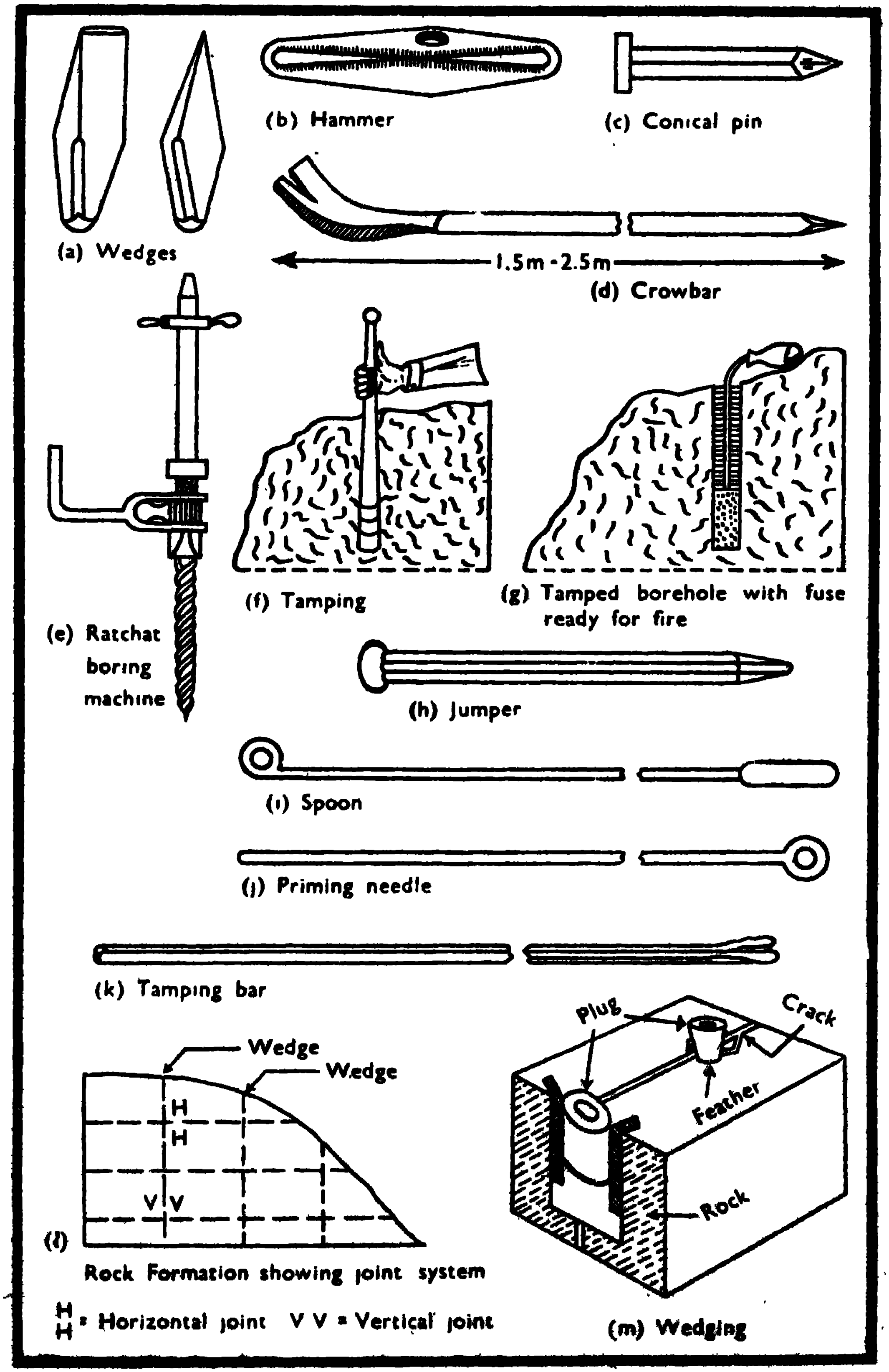


Fig. 1.5 Wedding

desicator. The specimen is then immersed in distilled water for 72 hours. The absorption is given by $\left(\frac{\omega_2-\omega_1}{\omega_1}\right)\times 100$, where $\omega_1$ and $\omega_2$ are initial weight of dry sample and final weight of wet sample respectively.

1.7.7 *Microscopic Examination*—The fractured surface of a durable stone should be bright, clean, and sharp with grains well cemented together. Stone likely to decay shows a dull earthy appearance. This is essentially a geologist's test.

1.7.8 *Attrition List*—The purpose of this test is to determine the effect of grinding action of traffic. "DEVILS' attrition test" machine has one or more cylinders mounted diagonally at an angle of 30° to the horizontal for about 5 hours at 30 revolutions per minute, the cylinder being fed with 5 kg. stone balls of 6 cm size. The content is sieved through 2mm sieve at the end of the rotation and the pieces retained by the sieve are weighed and loss in weight calculated.

Percentage of wear = $\frac{\omega_1-\omega_2}{\omega_1}\times 100$, $\omega_1$ and $\omega_2$ be the initial and final weights of the material. A good stone should give 2% loss only.

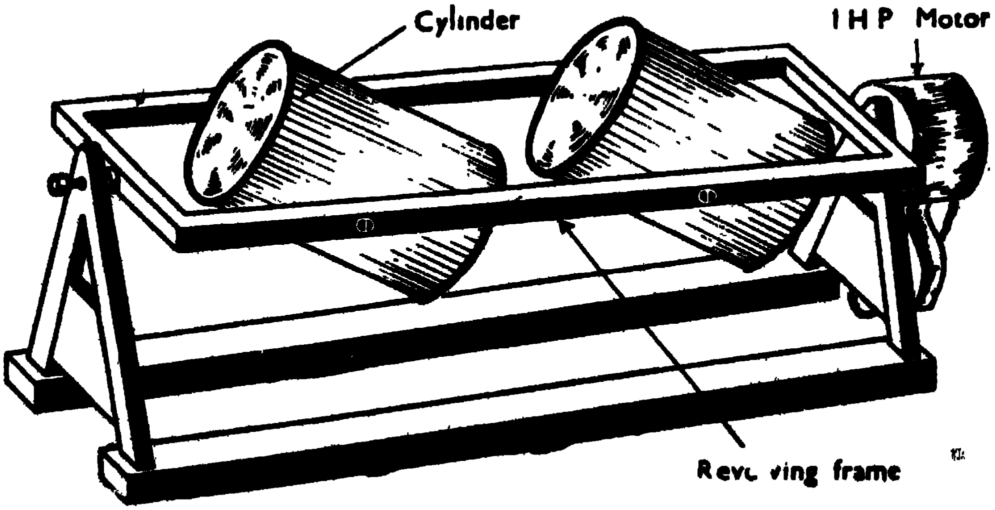


Fig. 1.6 Devil attrition test machine

## 1.8 Agents which destroy stones

The following agents destroy stones :

1.8.1 *Chemical Agents*—such as acids in the atmosphere.

1.8.2 *Mechanical Agents*—such as wind, dust, rain, frost, running water, pressure of sea, etc.

1.8.3 *Other Agents*—Lichens destroy limestone and worms or molluses destroy all stones except granite.

1.8.4 *Temperature Changes*—Different materials constituting the rock have different expansion and contraction which result in the deterioration of the rock.

1.8.5 *Dissimilar Stones*—When different types of stones such as lime stone and sand stone are used, the masonry cracks.

### 1.9 Preservation of stone

Stones may be preserved from the decaying action of the weather by the following methods :

1. Moisture is expelled from pores with the help of blow lamp and the surface is covered with a coating of coal tar, colourless paraffin oil, or any drying oil as linseed oil either mixed or unmixed with paint. This coating requires renewal and also spoils the appearance of the stone.

2. The stones to be preserved are to be washed with a thin solution of silicate of potash or of soda. After the silicate has become perfectly dry the solution of calcium chloride is applied freely. The two solutions combining form silicate of lime which fills the pores and common salt is washed out.

However, different types of stones require different treatment for their preservation. Plastering or painting is done in case of ordinary buildings. It is always better to use good stone rather to preserve the inferior stone.

### 1.10 Stone quarrying

It is the art of extracting stones for engineering purposes from natural rock.

1.10.1 *Site for Quarrying*—The rock at the surface is subjected to weathering and therefore is not so sound as that at a great depth where it possess greater density having been subjected to pressure. The stones are to be raised to the surface and so the depth to which we can go is limited from consideration of cost. Sides of hills are most suitable sites for quarrying as the rocks there are of high density and available at the surface.

The following factors, however, govern the location of a quarrying site.

**1.10.1.1** Availability of the required stone.

**1.10.1.2** Nearness to the existing road.

**1.10.1.3** Possibility of providing suitable drainage from the pit.

**1.10.1.4** Availability of slope for positioning the crushers and cutting and dressing of the rock.

**1.10.1.5** The building and other structures should be at a safe distance in case quarrying is to be resorted to.

**1.10.2** *Methods of Quarrying*—Stones are quarried either by hand tools or wedging, or by blasting with powder or dynamite, the blast holes being drilled either with hand or pneumatic tools. Wedging is adopted for taking out large rectangular blocks and blasting is for smaller blocks and road metals. Blasting is cheaper and quicker than wedging. Channelling machines are employed when stones are required in huge blocks. In this process Channelling machines are used for cutting oblique grooves with great speed upto depths of 3·7*m* ; the machines being driven by compressed air, or by steam or electrically. Blocks upto 24*m* × 3·7*m* × 1·5*m* size can be cut by this method.

**1.10.2.1** *Wedging*—In this method if vertical fissures in rock answer the size of required stones, steel *wedges* and *points* (Fig. 1.5*a*) are driven by *hammers* (Fig. 1.5*b*) through the fissures on the undisturbed side of the stone and thereby stone is shifted into the space previously formed by the removal of the block by blasting or by hammer and wedge. One side of the stone is raised by *crowbars* (Fig. 1.5*d*) and rollers put underneath and thereby it can be transferred to a truck or removed. If natural fissures do not exist to give the required size of stones, lines of holes are drilled at regular stort intervals in the required directions and *conical pins* (Fig. 1.5*c*) are inserted and struck simultaneously to produce cracks in stone along the line of holes. Then stone may be removed by wedging. There are various types of *borers* or *drills* (Fig. 1.5*e*) but when the stone is hard pneumatic drill is sometimes used.

**1.10.2.2** *Heating*—Granite and gneiss are quarried in a very simple way in Madras, Orissa, and Chota Nagpore. Stone cutters pile wood on the surface of rock and burn those steadily for some hours. The upper layer of stone expands and separates from the lower with a dull bursting sound. The loosened portion is then broken up to sizes.

**1.10.2.3** *Digging*—Good coral stones are found in the bed of seas.

Those are dug out with crowbars during low tides under nearly chest-deep water and removed to shore.

Various tools used in wedging, along with horizontal, vertical joints, plugs and feather etc. are shown in Fig. 1.5 (*a* to *l*).

**1.10.2.4** *Blasting*—It is quarrying stone with explosives specially for stones of a compact nature. This method should be avoided for building stones as it shakes the stone and also causes a good deal of waste. It is well suited for excavation, tunnelling through rocks and for quarrying large quantity of smaller stones down to the sizes of road metal. Care should be taken to cut the stones obtained by blasting so as to place them on their natural beds in buildings when required. The operations in blasting are *boring*, *charging*, *tamping* (Fig. 1.5*f*, *g*) *and firing*. In this method holes are drilled to the depth to which stone is to be split and the required amount of powder or dynamite is put into, tamped with earth or sand and fired with a fuse. In tunnelling numerous charges in a line of drill holes are fired simultaneously by electricity. The modern explosives employed are gun-powder, dynamite, nitroglycerine, blasting-gelatine, etc. Dynamite is now the commonest explosive met with as it is more powerful. It may be used in wet holes or even under water and requires no hard tamping, but it should not be used when it is required to blast large blocks of stones due to its violent action and shattering effect. It is extremely dangerous in a frozen state and so it is not suitable for use at high elevations.

The blast holes are made with a *jumper* (Fig. 1.5*h*). In drilling a hole one man alternately rises and drives the jumper while another man loosely holds the lower part of it directing it into the hole and rotating it each time. A little water is poured at intervals to soften the stone. When the hole is drilled to the required depth it is cleared of the debris by a *scraper or spoon* (Fig. 1.5*i*). Holes of small depth can be made by jumper but deeper holes in very hard rock must be drilled. The charge of gun powder or gun-cotton (dynamite) is put into it and the greased *priming needle* (Fig. 1.5*j*) or fused cord placed in position. The hole is filled up with damp clay in a small quantity at a time and firmly rammed or tamped with a *tamping bar* (Fig. 1.5*k*) with a care to turn the priming needle during the process to facilitate its withdrawal when tamping is finished. The needle is withdrawn and the space is filled with fine powder and this is fired by means of a slow fuse of which about 1 *m* length remains outside the blast hole so as to give time to the person firing it to retreat to a safe distance before the explosion takes place. Explosion occurs removing masses of stones round the hole. The useful effect of a blast depends greatly upon the judicious selection of the hole.

A good blast produces a dull sound and the mass of rock should be just displaced without being blown into fragments. The tamping material is firmly rammed to offer resistance to the explosive force of the powder and direct its action towards the line of least resistance. *Line of least resistance* (Fig. 1.7*a*) is the line by which the explosion of the charge will meet with the least opposition to its passage into the air. It need not necessarily be the shortest line from the charge to the surface.

The quantity of powder or dynamite necessary for each blast depends mainly on the nature of rock, the mass of rock to be removed and the position of the hole.

Ordinarily

$$\textit{Charge of powder in kg.} = \frac{(\textit{Line of least resistance in meter})^2}{8}$$

*When the line of least resistance be 1 meter then the quantity of* $\textit{powder} = \frac{1^2}{8} = 0{\cdot}12$ kg.

The weight of rock loosened is roughly ten thousand times the weight of powder used.

Special precautions are to be taken to avoid accidents during blasting by giving warning just before firing to enable coolies to retire to a safe distance and all explosives are carefully stored in a magazine specially built for this purpose.

Electric firing is resorted to by means of patent electric fuses and portable firing batteries when rock is very hard and rapidity of execution is an important factor. This method is preferred because (1) a large number of shots can be fired simultaneously which economise time and labour, (2) current is turned on at a great distance affording greater safety to workmen, (3) greater efficiency is obtained for explosives due to simultaneous firing, (4) there is no danger of hang-fire, and (5) it is specially useful for blasting under water.

**Composition of explosives**—Blasting powder or gun powder is a mixture of saltpetre, sulphur and charcoal in the protections of 65, 20 and 15.

The firing produces a slow heaving action and hence this type of explosive is useful where excessive shatwing is to be avoided. Nitro-

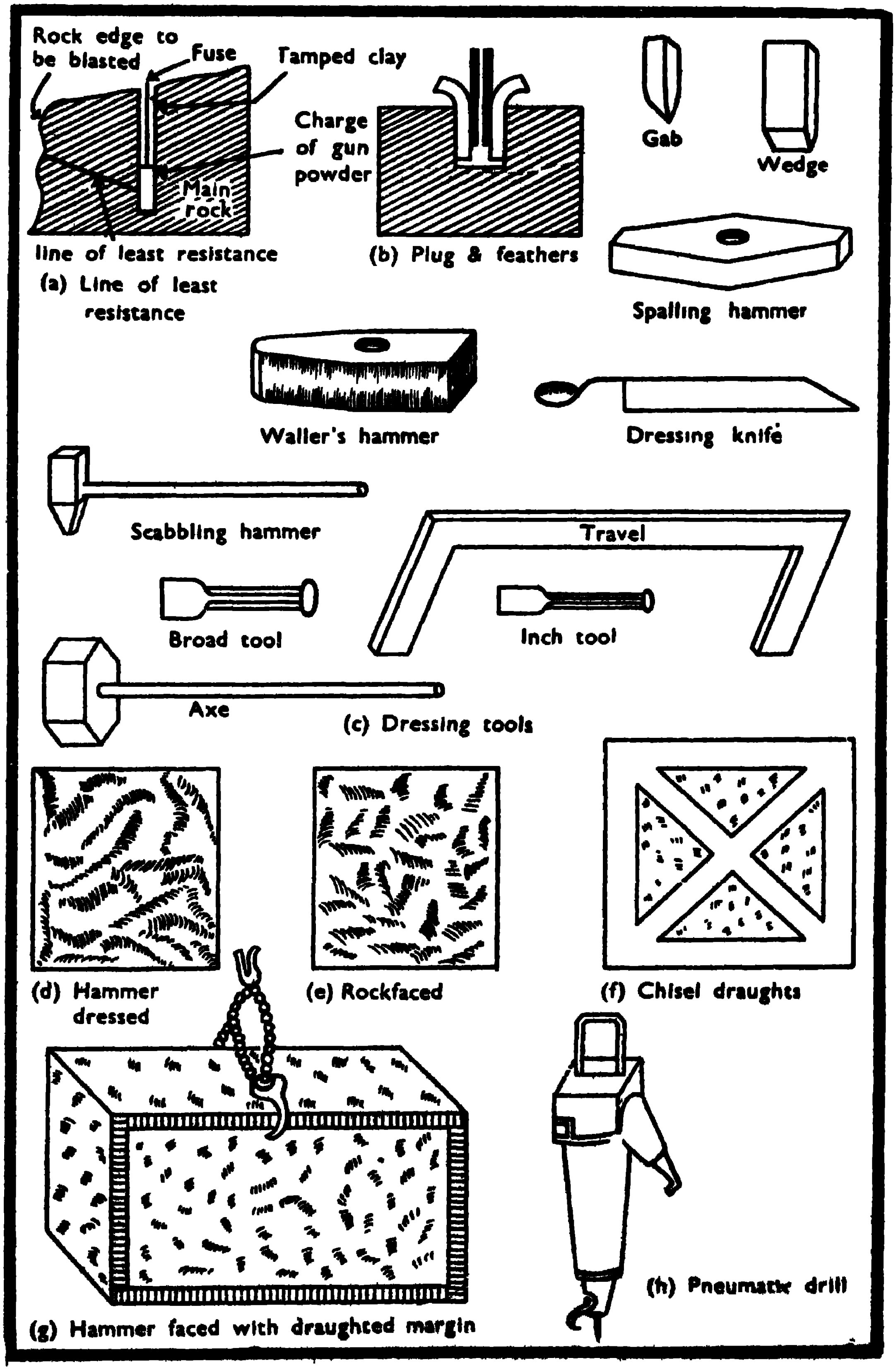


Fig. 1.7 Boring and drilling tools

glycerine is a semi-plastic paste containing 75% of the explosive oil called nitroglycerine absorbed in a silicate earth.

It is exploded by means of detonator which in its turn is fired electrically by a slow burning fuse.

One of the most powerful nitro-cellulose explosives known as guncotton is made by saturating gun in a mixture of nitric acid and sulphuric acid. It should be handled with great care as in its dry state it is highly inflammable.

**1.10.2.4.2** *Detonators.* There are two varieties of detonators namely plain and electric. The plain detonator is partly filled with mercury fulminate or any other explosive and the upper portion is empty to receive the fuse. The tube is 6 mm in diameter and 25 mm long. The complete assembly of the fuse and detonator is known as Capped fuse. The empty portion of the plain detonator is replaced by the fuse head assembly in the case of electric detonator. The details of this detonator are given in Fig. 1.8.

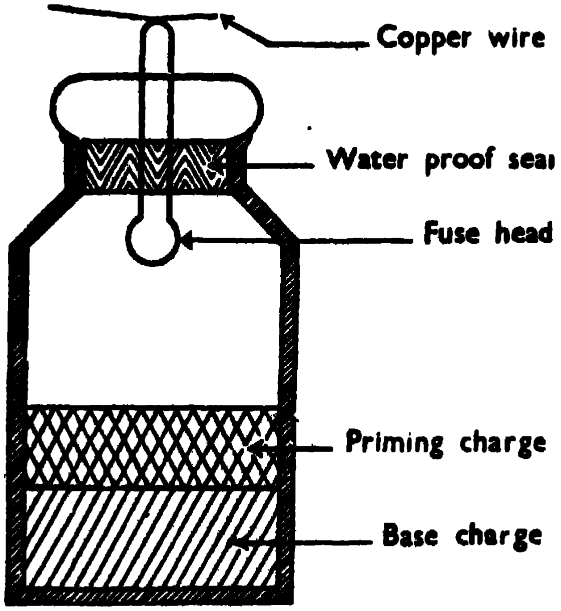


Fig. 1.8. Electric Detonator

The safety fuse is a thin cotton rope soaked in water proofing material. Depending upon the rate of burning required, it contains various quantities of explosive.

**1.10.2.5** *Storing of explosives.* A proper magazine apart from important buildings should be specially provided. No two explosives and their detonators should be kept in the same box.

### 1.10.2.6 *Comparison of blasting powder and dynamite*

1. Blasting powder is useful for quarrying large blocks of stones which would be shattered to pieces if dynamite is used.

2. Cost of blasting powder is about $\frac{1}{5}$th of dynamite.

3. $\frac{1}{4}$ kg of blasting powder will loosen about 2 $m^3$ of the rock whereas the same quantity of dynamite will shatter to pieces about 3 $m^3$ of the rock.

4. Dynamite can be used under water and requires no hard tamping.

5. Destructive power of dynamite is 6 times than that of blasting powder and so dynamite is useful for tunnelling and mining operation.

6. A primer cartridge is required for exploding dynamite. The primer cartridge as shown in Fig. 1.9 consists of a dynamite cartridge, detonator and a fuse.

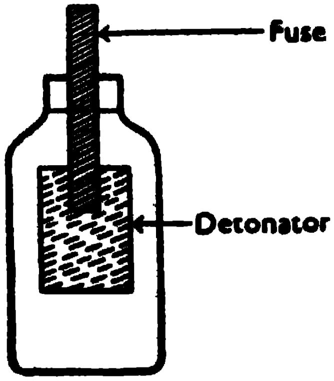


Fig. 1.9. Dynamite cartridge.

The dynamite cartridge is opened from the end meant for opening and a hole is made with the help of a brass needle to receive the detonator and fuse is then inserted in the space meant for this in the detonator.

Before dynamite is exploded, the prepared primer is placed gently on the top of dynamite charge and covered with a depth of 20 cm inert material.

**1.10.2.7** *Channelling machine or Channeller.* It is used when massive blocks of stones are to be quarried for use in dockyards, harbours and other marine works. It consists in cutting long narrow channels in the rock to free the sides of large blocks of stone. It is required to undercut the block in order to release it if the rock is not in layers. The block is taken out by means of wedges or *plug and feathers* (Fig. 1.7b).

**1.10.2.8** *Quarrying with Machines. Lifting large blocks* is done with the aid of cranes and derric poles, which are conveniently mounted on a trolly or a wagon. Mobile cranes are very convenient to move from place to place.

*Cutting and dressing blocks* are done with the aid of circular saws or reciprocating saws. The stone block is mounted on a trolly which brings the stones before the sawing machines. Machinery is also used for planing and polishing the finished surfaces of stone blocks and paving sets.

*Breaking, Crushing and Screening Machine*—Big pieces of stones and quarry spoils are broken to smaller sizes with jaw, gyratory or impact crushers. Subsequent to crushing, crushed materials are allowed to pass through fixed, movable or rotary screens for sorting the materials according to grades or sizes.

*Transporting the materials* in the quarry is done by a system of trolly lines or rails or ropeways. Motor trucks, tipping wagons, dumpers, cars, etc. are very commonly used.

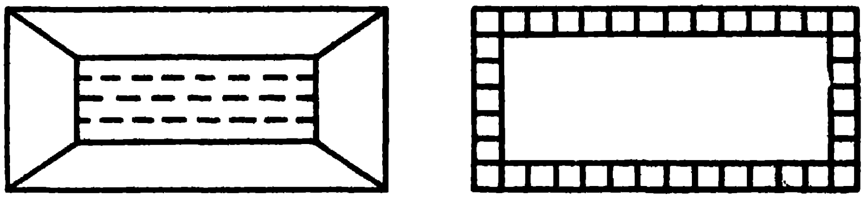
*Drilling machines* for boring holes in rocks are rotary type and percussion type but for deep holes impact drilling machines will be found very useful.

## 1.11 Dressing of stones

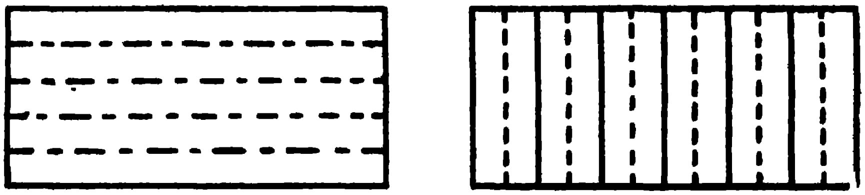
After quarrying, stones are to be dressed or wrought by *dressing tools* (Fig. 1.7c) to varying degrees depending on the kind of work for which they are meant. For rubble masonry stones are roughly dressed and such stones are called *hammer-dressed* (Fig. 1.7d) and *rock faced* (Fig. 1.7e). For ashlar work with thin joints a *chisel draught* (Fig. 1.7f) is first sunk round the margin of each stone and front face may be only roughly dressed or rock faced. If the whole face is to be truly smooth, draughts are cut around and across the stone with chisel and then chisel, axe or hammer is used to work down the intermediate portions into the same surface with the draughts. The fine grained stones are usually brought to a smooth surface by rubbing with sand.

It is usual to run a draught, about an inch in breadth round the margins of squared stones, even when dressed only with hammer or pick to ensure close fitting joints. The stones are then laid to the *hammer faced with draughted margins* (Fig. 17g.) with their parallel tool marks close together.

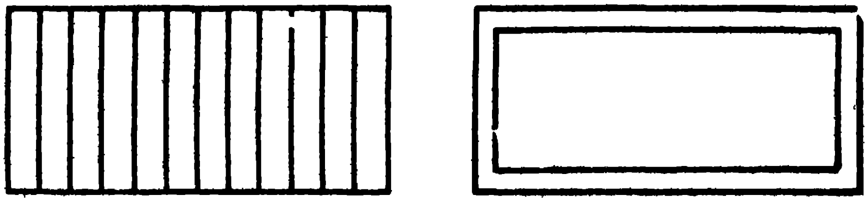
The position of the stone with respect to its own structure as well as with respect to its position in the building determines the required surface finish. Other factors which influence the surface finish are quality of the stone, architectural effect and the funds available. Hammer dressed or quarry faced surface finish is suitable for random rubble and coarse masonry. Rough tooled surface and tooled surfaces are suitable for exposed surfaces. Polished finishes are used where absolute cleanliness is required such as bath-rooms, hospital etc. Different types of finishes are given in Fig. 1.10.



(a) Hammer dressed (b) Rough tooled surface



(c) Tooled surface (d) Hand tooled surface



(e) Machined tooled surface (f) Polished surface

Fig. 1.10. Surface finishes.

### 1.12 Sawing and polishing stones

Soft stones such as limestones and marbles can be easily sawn but even hard stones like granite are also often sawn. Water is freely used during sawing and the saw used is called *frame saw.*

| NAMES OF STONES | COMPOSITION AND CHARACTERISTICS | USES |
|---|---|---|
| **Granite** | Consists of quartz, felspar and mica ; igneous, durable, hard and heavy; takes high polish. Sp. gr. 2·7, compressive strength 770-1300 $kg/cm^2$ | Used in bridge piers, marine works and ornamental columns. Quarry refuge for road paving crushed stone as ballast. |
| **Syenite** | Consists of quartz, felspar and hornblende ; igneous, tough and durable ; takes a fine polish. | Used in paving and ornamental works. |
| **Basalt** | Consists of felspar, augite, olivine and titanic iron ; igneous, hard but expensive to work. | Used for paving road metal and manufacture of artificial stone. |
| **Trap** | Consists of felspar and hornblende ; resembles basalt ; igneous, hard and tough ; particles have cementing matter. | Used for paving and road metal. |
| **Limestone** | Consists mainly of carbonate of lime ; sedimentary. Easier to work and dress. | Used for paving and road metal under light traffic, blast furnace, bleaching, tanning and manufacture of lime. Excellent building stone. |
| **Sandstone** | Consists of sand or quartz cemented together with lime, magnesia, alumina, oxide of iron or mixture of all ; sedimentary. | Hardest one for ashlar work, paving and road metal; fine grained ones for carving and coarse grained ones for rubble work; road metal with tough materials will be muddy in wet and dirty in dry weather. |
| **Slate** | Consists chiefly of silica and alumina ; metamorphic ; compact, fine grained, hard, tough, durable ; gives metallic sound when struck, and can be split into thin sheets along planes or cleavage. | Thin ones for roof covering but thick ones for floor, step, landing, shelve, still, bath, cistern, etc. ; used also as damp proof course. |
| **Marble** | Crystallised limestone ; metamorphic ; hard, takes polish and can be easily carved. | Used in columns, pilasters, stairs, table slabs, steps, floors, and other ornamental purposes. |

| NAMES OF STONES | COMPOSITION AND CHARACTERISTICS | USES |
|---|---|---|
| Gneiss | Metamorphic and stratified granite ; splits into thin slabs and easily worked. | Used in street paving. Rough stone masonry work Aggregate for concrete. |
| Dolomite | Contains carbonates of lime and magnesia ; metamorphic acted upon by sulphuric acid. | Used as paving and building stone, road metal under light traffic but not used in manufacturing town. |
| Serpentine | Igneous ; compact and soft ; striped appearance resembles the skin of a serpent. | Used for decorative purposes. |
| Porphyry | Igneous ; very hard, tough and resembles granite. | Used as road metal and ornamented building stone. |
| Laterite | Sandy clay stone containing high percentage of iron oxide. | Used as building stone and road metal. |
| Kankar | Impure limestone. | Used as road metal for the light traffic and yields hydraulic lime. |
| Singles | Water-borne pebbles found in river beds. | Broken shingles used as road metals and in concrete when no better stuff available. |
| Gravel | Mixture of water born pebbles with sand. | Used for surfacing road, blindage and also in concrete. |
| Quartzite | Crystalline, compact, hard, brittle and particles have no cementing matter. | Used as road metal and concrete aggregate. |
| Murum | Decomposed laterite. | Used as blindage for metalled roads and in garden walks for red colour. |

Stones like granite, trap, marble, etc. take a good polish and are used for ornamental work after polishing by polishing machines.

### 1.13 Commonly used stones

There are innumerable varieties of stones existing on the face of the earth and so an attempt is made above to briefly describe stones commonly used in the construction of engineering structures.

### 1.14 Classification of sandstone

1. *Flag stone*—It is a thin bedded variety of sandstone, easily splits into thin slabs and is used for paving.

2. *Tile stone*—It is similar to flag stone but splits into very thin slabs and is used for roofing.

3. *Free stone*—It is the sandstone that can be cut to any shape easily.

4. *Grit*—It is a strong and heavy sandstone obtainable in large blocks and used for heavy engineering works.

### 1.15 Classification of limestone

1. *Marble*—It is hard, takes polish and is used for columns, pilasters, staircases, hearths, table-tops, steps, floors and other decorative purposes.

2. *Compact limestone*—It is easily cut and dressed by masons, and suitable for engineering structures when tough and durable. It is used for paving or road metal under light traffic, in blast furnaces and also in bleaching, tanning and other industry. It is also the principal source of fat lime. It is affected by acid of the atmosphere of a manufacturing town.

3. *Granular limestone*—It is soft, light and absorbent.

4. *Shelly limestone*—It consists mostly of shells and is chiefly used for paving purposes.

5. *Magnesium limestone or dolomite*—It consists of carbonate of lime and magnesia with iron, silica and alumina. It should not be used in manufacturing towns as it is attacked by sulphuric acid fumes.

6. *Kankar*—It is the most impure limestone. It occurs a few feet below the surface of earth. It yields hydraulic lime and makes good road metal when hard and free from earthy matter.

*Chalk* is pure limestone and is used in the manufacture of portland cement and in the preparation of glazer's putty. ***Shingles*** are water borne pebbles found in river beds and are used as road metal and concrete aggregate when better stuff is not available at a reasonable cost.

## 1.16 Slates

It is metamorphised argillaceous rock of various colour. It was originally a sedimentary rock formed by deposits of clay but will not divide along the natural planes of bedding which are no longer traceable but splits easily along planes of slaty cleavage which are caused by intense lateral pressure. These two planes may coincide or may not. If they do not coincide they split easily into thin, light, smooth, compact and impervious slates and are most suitable for roof covering but when they nearly coincide then they cannot be split into thin smooth slates and so cannot be used for roofing slates as large scantlings are required but make excellent slates for paving and this is the case with Indian slates. So there are two kinds of slates—(1) true cleavage slates and (2) compact slates in which planes of splittings are not the cleavage planes.

There is also line of imperfect cleavage in slate and generally slate suddenly cracks along this imperfect cleavage line when got struck. During the cutting of slate this line is generally kept parallel to the length of the slate. In slant roof this line is parallel to the slope and in flat roof at right angle to rafters.

Indian slates are found in Simla and Gurgaon (Punjab) Cuddapah (Tamilnadu), Chanda (M.P.), Monghyr and Singbhum (Bihar), and in Mysore and Maharashtra.

**1.16.1** *Method of quarrying slates.* Rock is worked in tunnels one above the other, the blocks are blasted and broken into required widths. Those are then split into thickness of about 7·5 cm, cut by saw into suitable lengths, split into thinner slates and then squared.

**1.16.2** *Characteristics of a good slate.* (1) It should give a sharp metallic ring when struck and should not splinter at the edges. (2) It should be hard, tough, smooth, uniform in texture and of good dark colour.

Soft slate will absorb moisture, nail holes in it will be enlarged and so the slate will get loose but very hard slate will be brittle and so will fly into pieces when squared or holes are made in it.

In short, a good slate is of an even colour, fine grained, compact, hard and tough, non-absorbent, free from blemishes of any kind and gives a sharp metallic sound when struck.

1.16.3 *Tests*. A good slate should absorb no water and it can be tested by weighing the slate when thoroughly dry and wet. Water won't rise in the upper part of an upright good slate dipped half its length in water. Earthy odour from wet slates will indicate that the slates will not stand weather.

### 1.17 Artificial or cast stone

It is obtained by artificial means. Many processes have been invented for the manufacture of artificial stone as it is difficult to obtain durable natural stones at a moderate cost in many localities. It cannot be used extensively in ordinary buildings for its great expense, but it can be moulded into most intricate forms easily and so it is most economical when it is substituted for the carvings and ornamentations in natural stone. For practical use it is formed into mortar or is used as concrete.

It is durable and has capacity to resist wear and damage during building operations. In the hollow blocks the air spaces in the walls provide insulation against heat, cold, damp and sound the cavities can be used for conveying pipes and electric wires.

### 1.18 Classification of artificial stones

It is classed as follows :—

1. *Simple cement concrete or cement concrete subjected to hardening process*—such as, *Victoria stone.*
2. *Chemical stones*—such as, *Ransome's patent stone.*
3. *Artificial stones from melted natural stones*—such as, *artificial marble.*

1. *Victoria stone*—Crushed granite and portland cement in the proportion of 4 : 1 are mixed with required quantity of water and allowed to set for 3 or 4 days into a mould to the required shape. It is then immersed in silicate of soda for a week when it is as hard as stone. It is used for paving, window sills, copings, stairs, landings, etc.

2. *Ransome's patent stone*—It is made by mixing dry sand with silicate of soda and a small portion of powdered stone or chalk. These are thoroughly mixed in a pug-mill and forced by hand into moulds. A solution of chloride of calcium in cold state is poured over the blocks,

turned out to make them hard and then the blocks are immersed in a boiling solution of the same chemicals until pores are entirely filled with the solution, when the blocks are found to be as hard as any natural stone. It is used in Nawab's Palace at Murshidabad, and Bombay Post Office but the cost is greater than that of natural stone.

3. *Artificial marble*—It is made by fusing and moulding constituent mixture, which is composed of 80 parts of plaster in powder; 20 parts of pulverised marble, 20 parts of sulphate of potash with a 5% solution of glue mingled together with water. It is mostly used in France.

4. *Terrazzo*—It is the name given to a mixture of marble chips with white cement and some pigment. It is used for making slabs for face of walls or floors. It may be either precast or laid in situ on wall or floor surface.

### 1.19 Reconstructed Stone

Lime made from dolomite is mixed with lime stone quarried and crushed into grit and heated to 980°C to drive off $CO_2$. The residue of CaO and MgO, which is in the form of powder is stated by mixing with water and converted into blocks under pressure. The hydrate of lime blocks is carbonised by fading $CO_2$ and the blocks are then dried.

### 1.20 Bituminous Stone

For forming bituminous stone, granite stones are soaked in refined bitumen. Such stones are durable and are suitable for wear and dust resisting stone surfaces.

### 1.21 Fire and Electrical Resistance by Stones

Stones should have a homogeneous composition having equal coefficient of expansion and be free from calcium carbonate or oxide of iron, which acts as flux for *fire resistance* but those should be non-absorbent like slate or marble for *electrical resistance*.

### 1.22 Precautions for stone users

1. In quarrying stone, take out blocks in sizes within natural limits.

2. Use stone in compression and never in tension.

3. Put pressure upon stone at right angle to its natural bed.

4. Do not use compact stones, which become slippery, for stairs and pavements.

5. Do not use friable stones when exposed to rubbing or weather.

6. Get roughly rectangular block from quarry which may be dressed easily and with little waste.

### 1.23 Specification for road metal, concrete aggregate and railway ballast

Hard, heavy, angular compact and elastic road metal which is clear and 5 cm gauge shall be used. For top dressing during rolling 2 cm screenings shall be used. The dust produced by the road metr' screenings shall have cementing property.

For concreting work, hard, strong, and heavy material having rough surface and free from all impurity shall be used. For foundations and massive work it shall pass through a ring of 5 cm diameter whereas for floor, lintel and roof work it shall pass through 2 cm diameter ring and the aggregate shall be soaked in water before mixing.

Strong, hard, durable and elastic aggregate passing 5 cm ring shall be used as ballast for railways.

### 1.24 Stone quarries of different States in India

*Assam*—Kankar from Khasia and Jaintia hills ; limestones of Lakhimpur and Sibsagar, and slates of Naga hills.

*Bengal*—Quartzites of Bankura ; sandstones of Burdwan and gneiss of Darjeeling.

*Bihar and Orissa*—Laterite of Cuttack and Sambalpur, limestones of Gangapur, Manbhum, Palaman and Sahabad ; sandstone of Hazaribag ; schist of Monghyr ; basalt of Santal Parganas and slates of Singhbhum.

*Uttar Pradesh*—Sandstones of Agra and Allahabad ; quartzites of Almora ; slates of Dehra Dun ; kankar of Jalaun and marbles of Mirzapur.

*Rajasthan*—Limestones of Ajmer-Merwara ; marble of Alwar, Joypur and Marwar ; sandstone of Bharatpur and Bikaner ; and Dolomite of Marwar.

*Punjab*—Slate of Kangra ; limestones of Patiala and Simla.

## EXERCISE I

### A. M. I. E. (I) Examination Questions

1. Describe the process of quarrying and dressing granite for building purposes. What are the requirements of good building stone ? (May 1962, Nov. 1958)

2. (a) Explain briefly : (i) igneous rock, (ii) sedimentary rock, and (iii) metamorphic rock. (b) What are the chief characteristics of a building stone ? (c) Comment on the following as building stones and their specific use in building construction : (i) granite, (ii) sandstone, (iii) marble. (Nov. 1961)

3. (a) What are the main classifications of rocks ? Mention the chief constituents of stones. (b) Enumerate the characteristics of good building stones. (c) State, with reason, the kind of stone you would recommend for use in the construction of artificial stone. (May 1960)

4. Enumerate the characteristics of a good building stone. What are the different methods used in dressing it ? (Nov. 1957)

5. Write short notes on : (a) quarrying of marble and granite, (b) quarrying by blasting. (Nov. 1956)

6. Classify the different types of building stones and point out their suitability in building and paving works. (May 1955)

7. Mention the relative values of granite, sandstone and marble as building stones. How can they be economically substituted ? (Nov. 1954)

8. (a) Describe, in brief, methods used for quarrying stones for building work.

(b) How do natural stones decay ?

(c) Which of the mortars, lime or cement, would you prefer for stone masonry and why ?

(d) What are artificial stones ? Describe, in brief, the process of preparing artificial marble. (May 1954)

9. (a) Describe the principal constituents of stones based on their chemical composition.

(b) Enumerate the characteristics of good building stones.

(c) State, with reasons, the kind of stone you would recommend for use in the construction of : (i) external wall of a building, situated on the sea shore (ii) platform of a railway goods shed ; (iii) ornamental cornice of a building. (Nov. 1953)

10. (a) A masonry dam in stone is to be constructed across a river. What are the essential qualities you will look for and how would you test the suitability of the stones for the purpose ?

(b) Enumerate briefly the sequence of operations necessary to produce coursed-rubble blocks on a large scale.

(c) Name the tools and plant that are required for the job. (May 1953)

11. Name some of the principal stone quarries in India, mentioning the type of stone they produce. What are the qualities you would look for in good building stone for masonry work ? In opening a quarry why should the surface stone be rejected ? What natural features will indicate whether the stone can be quarried by wedges ? (Nov. 1952)

12. (a) What are the different tests applied to test the suitability of stones for structural use and what are the factors affecting the durability of stones ?

(b) What are the materials required in blasting ? Describe the process of blasting rocks. (May 1952)

13. (a) Give specifications of stone-dressing for different classes of stone masonry : (i) Ashlar, fine ; (ii) Coursed rubble, first sort ; (iii) Uncoursed rubble.

(b) State clearly what precautions you will take in using a building stone with laminated structure in : (i) cornices with undercut mouldings ; (ii) pillars ; (iii) arches. (May 1951)

14. (a) What is the natural bed of stone ? Why should a stone be set in a structure upon this bed ?

(b) How would you classify stones used for engineering work ?

(c) What are the tests to which a stone should be subjected before it is selected for building purposes ?

(d) What are the agents that destroy stone ? (Nov. 1950)

15. (a) State the general characteristics of good building stone.

(b) Given, samples of following stones, how would you identify them : granite, kankar, sandstone, laterite ? Under what suitable scientific classification do those stones fit in ?

(c) Mention half a dozen important explosives used in blasting stones. (Apr. 1950)

16. (a) What are the main principles to be observed in quarrying a rock ? Illustrate your answer with sketch.

(b) State the sequence of a good building stone and mention any time of good building stone available in your state, giving the characteristic and geological structure. (Nov. 1962)

17. (a) Explain the different classifications of stones, giving an example of each.

(b) State the main types of stones used for buildings in India with their places of availability. (May 1963)

18. What are the types of explosives generaly used ? Explain how they are normally obtained and stored before use.

How is blasting carried out and what precautions have to be carried out for the safety of workmen. (Nov. 1963)

19. Name and describe any five varieties of Indian stones. In what part of the country are they available in sufficient quantities ? Describe their properties and suitability for various types of construction. (May 1965)

20. Explain briefly what you understand by :

(i) Igneous rock.

(ii) Sedimentary rock.

(iii) Metamorphic rock.

Give example of each type and state their uses in building construction. (Nov. 1966)

## Other Examination Questions

21. Name some of the principal stone quarries in India.

22. What do you mean by the 'natural bed' of a stone and why should that be found out before using the stone in a structure ? How should it be placed in a building ? Give reasons for your answer.

23. Describe briefly with neat sketches the process of blasting rock, mentioning the tools used in the operation and state how you would regulate the power charge. What is the object of tamping ?

24. What is artificial stone ? Describe the method of making Ransome's patent artificial stone and compare its advantages and disadvantages to those of natural stone. In what sort of work is artificial stone superior to natural stone ?

25. What are the qualities that you would look for in stone metal for road making ? Where do you get them from in your State ? State why quartz is not good for the purpose.

26. Give a specification for road metal.

27. Name the stones, with their sources of supply that are used in your State for—(a) road making both for light and heavy traffic, (b) building concrete, (c) railway ballast, (d) structure of a building, (e) pavement, (f) bed stone for girder, (g) concrete for light roof terrace, (h) reinforced concrete, (i) garden walk, (j) break water, (k) decorative works, (l) ashlar masonry, and (m) damp proof course.

28. Name six kinds of stones generally used by Engineers in India and describe their composition, characteristics and uses and also state where they are available in India.

29. Arrange the following stones in order of their degree of hardness and durability—trap, ballast, marble, granite, sandstone and limestone. In the list of stones given above, which would you select as most suitable for aggregate, road metal and railway ballast ? Give reasons for selection.

30. You are asked to collect materials for constructing a building having architectural features. State what points you will consider in selecting the quarry or quarries for the supply of the stones.

# Chapter 2

## BRICKS, TILES TERRA COTTA, ETC.

### 2.1 Introduction

There are many different forms, such as, (i) *bricks*, (ii) *tiles*, (iii) *earthenwares* and *stonewares*, (iv) *terra cotta* and *other clay wares*, in which clay after it is burnt or baked is used by Engineers and Architects. Clay when moistened possesses a high degree of tenacity and plasticity and is very useful for making bricks, tiles, etc.

### 2.2 Bricks

Bricks are generally divided into four different classes according to their qualities, such as, *1st class*, *2nd class*, *3rd class*, and *jhama* bricks.

Brick like stone is largely used in architectural and engineering construction depending on its availability, economy, and other considerations for a work in a particular locality. Its comparative cheapness, the ease in handling, and the facility of work, are its important characteristics. When properly made it is nearly as strong as stone. It is really an artificial stone. It is now a relatively less important material of construction due to the developments of cement industry in Europe and America but in India it will still be an important engineering material for years till the developments of steel and cement industries in this country. Brick is made of clay or other suitable earth subjected to several processes, formed to the desired shape, dried and burnt. Pure clay contains silica and alumina in chemical composition as hydrated silicate of alumina. It is deficient in some ingredients essential for the manufacture of good bricks and so varieties of clay are mixed together or missing ingredients are added to it.

কাঁথি
( [illegible] )

## 2.3 Composition of Brick Earth

For the preparation of brick, clay or other suitable earth is formed to the desired shape after subjecting to several processes. After this the moulded bricks are dried and burnt. Silica and alumina in chemical composition in the form of hydrated silicate of alumina form pure clay. Pure clay is deficient in certain materials which are necessary for the manufacture of good bricks and hence some other variety of clay or the deficient constituent is added to the earth.

The composition of various constituents for a good brick is : (i) alumina 20 to 30% (ii) silica 50 to 60% (iii) lime. magnesia, oxide of iron etc.

The purpose of adding the above constituents is to get a mixture of clay and sand which after mixing with water and moulding will dry without shrinkage, cracking or warping. The presence of small quantity of finely divided lime enables silica to melt at furnace heat and thereby bind the brick particles together. If this is in excess there is danger of brick running together and becoming vitrified. The presence of small quantities of iron oxide also acts as flux like lime and imparts the characteristic red colour to the bricks.

## 2.4 Properties of good brick earth

A good brick.earth should be mixture of pure clay and sand so that when prepared with water it can be easily moulded and dried without shrinking, cracking or warping. It should contain a little finely divided lime which enables silica to melt at furnace heat and binds the particles of brick together, but not so much as to make the bricks run together and become vitrified. It should also contain a small quantity of oxide of iron which acts at flux like lime and moreover colours the brick red on burning.

### Properties of useful and harmful ingredients in brick earth

1. *Alumina* is the principal constituent of clay. It makes earth plastic to enable the clay to be moulded. But a brick containing too much of alumina with insufficient sand shrinks, cracks or warps in drying and becomes very hard during burning.

2. *Silica* exists in clay either in chemical combination with alumina as silicate of alumina or in mechanical mixture as sand. Free silica or sand, if not in excess, preserves the form of brick at high temperatures and prevents shrinkage, cracking, warping, and undue hardness, but too much sand destroys the cohesion and makes the brittle and useless.

3. *Lime* diminishes the contraction of raw brick in drying, enables silica to melt during burning and binds the particles of brick together but lime in excess causes the brick to melt and loose its shape.

4. *Oxide of iron* acts as a flux like lime enabling silica to melt during burning and binds the particles of the brick together giving hardness and strength. It also colours the brick red on burning but excess of it makes the brick dark blue.

5. *Magnesia* in brick earth makes the brick yellow.

6. *Iron pyrities* in brick earth oxidise, crystallise and spit the brick.

7. *Limestone* is detrimental to brick earth. It becomes quick lime during burning, slakes and splits the brick when wetted or exposed to weather.

8. *Alkalies* in excess act as a flux and cause the brick to melt and loose its shape.

9. *Potassium & sodium chlorides* and other salts render brick earth unfit for brick-making. They act as flux in burning causing bricks to crack, twist or warp. The brick containing salts absorbs moisture and the dampness causes efflorescence.

10. *Reh and Kallar*, which consists of sulphate of soda mixed with common salt and carbonate of soda, are totally unfit for brick making. They prevent bricks from being properly burnt.

11. *Grits or pebbles* of any kind in brick earth are harmful for brick-making. Bricks containing grits crack and cannot be worked readily.

## 2.5 Practical classification of brick earth

Brick earths are generally divided into three classes :

1. *Plastic, strong, or pure clays* consist of silica and alumina with a small percentage of lime, magnesia and other salts. Pure clay if used alone will shrink, crack and warp in drying and becomes very hard during burning. In the manufacture of bricks these pure clays are improved by the addition of sand or loam to prevent shrinkage and with ashes to provide alkalies or lime as flux. These are also known as *fat or foul clays.*

2. *Loams, mild or sandy clays* consist of free silica (sand) and clay. They are loose and sandy. Sand in clay prevents shrinking, cracking, and warping, and reduces its hardness. These require flux to fuse and

bind the particles together and so they are sometimes corrected by the addition of fat clays.

3. *Marls, chalks or calcarious clays* consist of a large proportion of carbonate of lime (chalk). These make good bricks and are often used without the addition of other substances, such as, sand and lime. *Malm or washed earth,* which is an artificial imitation of natural marl, is a compound of clay and chalk gives the best result. It is used when bricks of superior quality are required.

### 2.6 Analysis of some brick earths

The following table gives the proportion of the ingredients in some brick earths :—

| No. | Name of brick earth | Silica | Alumina | Oxide of iron | Carbonate of lime | Carbonate of magnesia | Soda and potash | Organic matter |
|---|---|---|---|---|---|---|---|---|
| 1 | Plastic clay | 49·5 | 34·3 | 7·7 | 1·5 | 5·0 | ... | 2·0 |
| 2 | Loam | 66·2 | 27·0 | 1·3 | 0·5 | ... | ... | 5·0 |
| 3 | Marl | 43·0 |  | 3·0 | 46·5 | 3·5 | 4·0 | ... |

### 2.7 Test of clay

If prepared clay to the consistency of moulding be clayey, it will adhere to the finger but if good, it will leave them clean. The quality of clay for brick-making is generally tested by making a few bricks out of the clay and by exposing them to sun and wind. If the bricks crack in drying it shows that the earth is very plastic and requires to be mixed with sand, but if they are brittle, *i.e.*, break easily by dropping them down on the ground, it shows the presence of too much sand in the clay and are apt to run into Jhama. If the bricks are not satisfactory after burning them in a simple kiln, chemical analysis will suggest what might be added to make it a good brick earth.

### 2.8 Brick-making

The manufacture of bricks involves the following four distinct operations :—

1. **Preparation of brick earth,** 2. **Moulding,** 3. **Drying, and** 4. **Burning.**

**2.8.1** *Preparation of brick earth.* The operation consists of:

**2.8.1.1** *Unsoiling.* Before the surface of the site from which clay is to be dug out is stripped off its turf the factors given below in respect of the selection of site have to be considered : (For details see IS : 2117 of 1967).

(i) Water table should be at least 1 m. below the kiln floor
(ii) The site should be in conformity with prevailing town planning requirement.
(iii) Suitable clay for brick making should be available.
(iv) Nearness of rail head or transport facilities.

**2.8.1.2** *Digging and weathering.* The clay is dug out before rains and laid on levelled ground a little below the general surface. Sand and other materials are added if required. These are left to weather for a few months. In some cases clay is dug out only a week before use.

Generally 1·5 to 2·5 $m^3$ of clay measured before digging are required for 1,000 bricks depending upon quality of clay, its treatment and the size of brick.

**2.8.1.3** *Clearing from stones.* Stones in clay are carefully picked out by hand but if in excess the clay is washed and strained through gratings for separation.

**2.8.1.4** *Grinding.* Clay, when hard and full of lumps, is ground into powder in *clay crushing roller* [Fig. 2.1(a)] by passing it between cast iron or stone rollers set sufficiently close together.

**2.8.1.5** *Tempering.* Clay is then tempered by being thoroughly broken up, watered, kneaded well under foot till it becomes quite a homogeneous mass. It is then covered up with mats and allowed to dry slowly till it is soft enough for moulding. The preparation of clay to make it homogeneous for the manufacture of superior brick is a very laborious process and can be simplified and better done by the use of *Pug-mills* [Fig. 2.1(b)] which are circular iron chambers or tubs of 1 to 2 m in height, and of diameter 1 m at top. The vertical iron shaft at the centre carrying arms with vertical knives can be turned by a long wooden arm with the help of one or two pairs of bullocks. Roughly mixed clay is put in at the top and required quantity of water is added to moisten it. When the long arm is turned by bullocks, the shaft moves and the knives cut and break all lumps in clay and mix up clay until it is a homogeneous mass. The clay passes out through an opening D at the bottom between timber pieces due to its own weight. There must be a ramp down

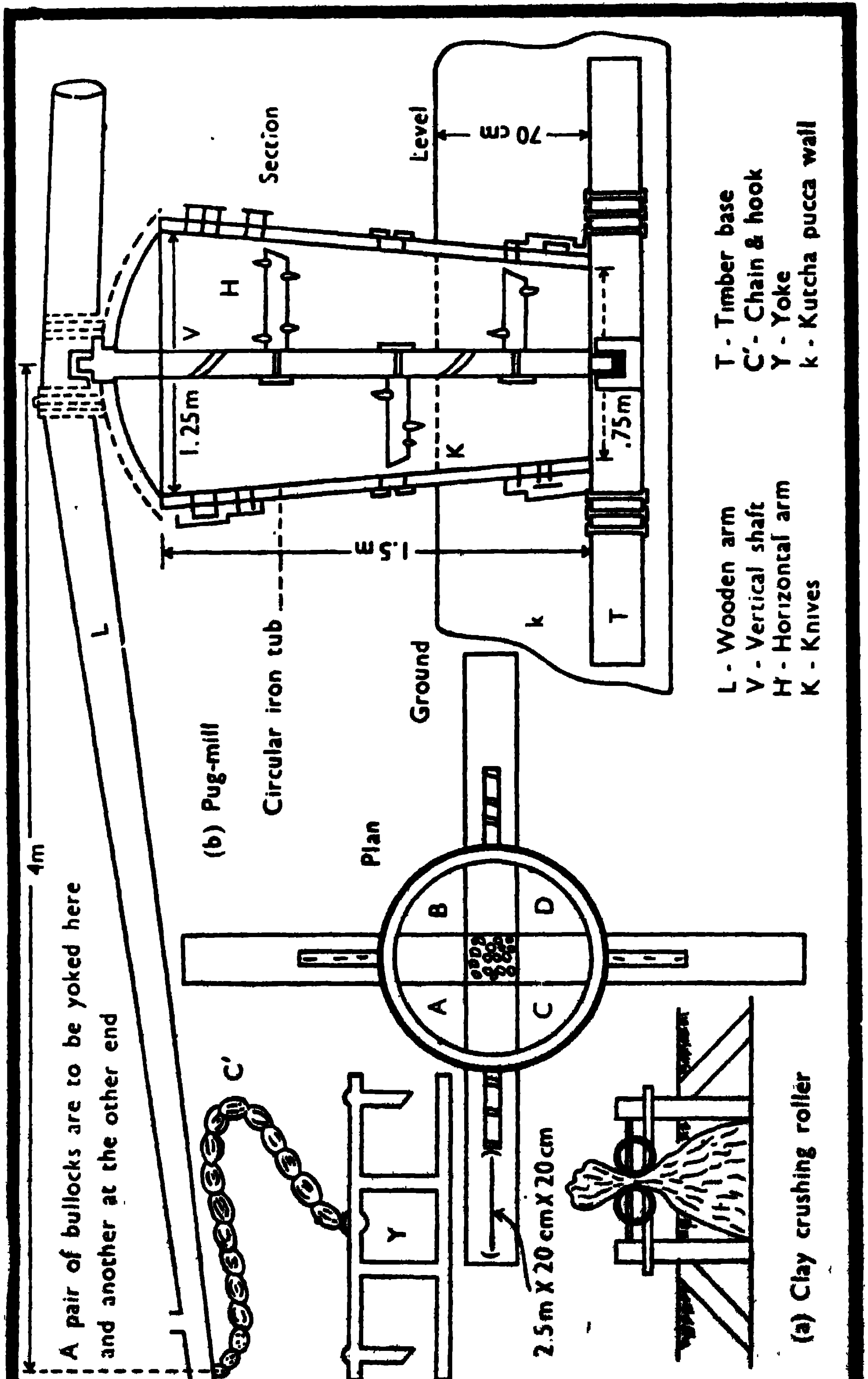


Figure 2.1 Pug Mill

to the opening D at the bottom for the tempered clay to be taken away. The quadrants A, B and C are permanently shut up with bricks but D is only shut up when the clay is first put in and kept so until clays are sufficiently tempered. The mill should be kept full for thorough mixing. One man puts in earth at the top and another man passes the pugged earth for brick-making. The mill is sunk 1 m into the ground so as to lessen the rise of the barrow run, to allow the clay to be conveniently thrown in from above and to avoid having a raised track for the bullocks. The 1 m sized mills are easily turned by a pair of Indian bullocks and the pugged earth for 12,000 to 15,000 bricks can be turned out in a day. English mills are very heavy for Indian bullocks.

The whole *brick-field* (Fig. 2.2) should be laid down on a plain. Curf-ground, drains, pug mills, moulding grounds, hacks, kiln grounds, and pucca brick stacks must be shown on plan before turf is turned. Then sufficient quantity of earth is dug up and placed on the curf-ground. The pug mills at 40 m apart are placed near the curf-ground and the tables near the mills. Hack should be in lines and the barrow run well dressed. There should be 6 moulding tables and 18 hacks for each pug-mill. The hacks are spaced 2·25 m centre to centre and are 1 m wide at top. The hacks are about 15 cm high and 85 m in length to accommodate 1,000 bricks in a row. The 30 m length of the kiln ground should be raised 30 cm and properly dressed and drained. The ground should have frontage of 360 m but the length from front to the rear will depend upon the number of working seasons. The field should be ready for moulding by the 1st week of November and moulding should be completed by the end of February so as to finish the work before the rains. During these four months each pug-mill will turn out earth for 8 lacs of bricks.

The following men are employed for working each pug-mill :

| | | |
|---|---|---|
| Moulders | Working cuckholds ... | 2 |
| Clot Moulders | Tempering and barrowing clay to pug-mill ... | 4 |
| Barrow-men | Driver ... ... | 1 |

Each pug-mill with its appendages will cost Rs. 1,550·00 approximately as shown below :

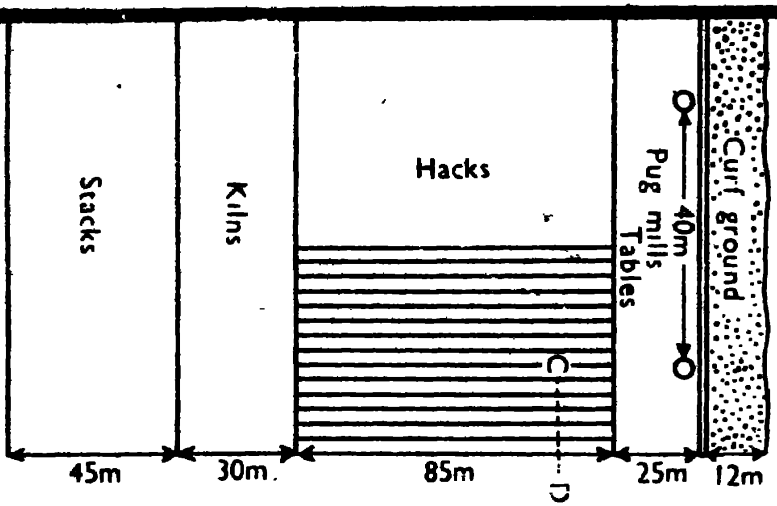
| | | | | Rs. P |
|---|---|---|---|---|
| 1 | Pug-mill complete | @ Rs. 600·00 | each | 600·00 |
| 6 | Tables | „ 20·00 | „ | 120·00 |
| 6 | Sounding post | „ 0·50 | „ | 3·00 |

| | | | | | Rs. P |
|---|---|---|---|---|---|
| 3 | Navy barrows | @ | 30·00 | each | 90·00 |
| 6 | Hack barrows | ,, | 30·00 | ,, | 180·00 |
| 2 | Cuckholds (Concave Shovels) | ,, | 2·00 | ,, | 4·00 |
| 6 | Water bowls | ,, | 0·20 | ,, | 1·20 |
| 6 | Pages | ,, | 3·00 | ,, | 18·00 |
| 6 | Iron moulds | ,, | 6·00 | ,, | 36·00 |
| 300 | Pallet boards | ,, | 0·20 | ,, | 60·00 |
| 1,000 | Strikes | ,, | 0·05 | ,, | 50·00 |
| 2 | Plank ladders (7 m × 6 m × 7·5 cm) | ,, | 40·00 | ,, | 80·00 |
| 1 | Plank (7 m × 25 cm × 7·5 cm) | ,, | 30·00 | ,, | 30·00 |
| 3 | Shovels | ,, | 5·00 | ,, | 15·00 |
| 3 | Kodalies | ,, | 4·00 | ,, | 12·00 |
| 1 | Tempering-hoe | ,, | 1·50 | ,, | 1·50 |
| 1 | Bucket | ,, | 5·00 | ,, | 5·00 |
| 6 | Hack lines | ,, | 0·80 | ,, | 4·80 |
| 6 | Crowding barrows | ,, | 30·00 | ,, | 180·00 |
| 6 | Plank (5 m × 20 cm × 5 cm) | ,, | 10·00 | ,, | 60·00 |
| | | | Total | Rs. | 1550·50 |
| | | | | Say Rs. | 1550 |

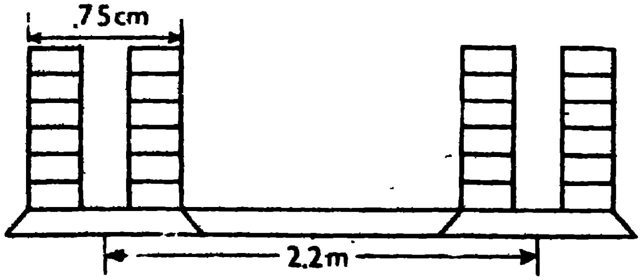
**2.8.2** *Moulding.* The brick earth thus prepared may be moulded either by hand or by machine. Hand moulding is mostly adopted in India and may be done either on ground or ~~on~~ table producing *ground moulded bricks* or *table moulded bricks.*

Moulding done by hand is called *hand-moulding. Slop moulding* is one in which the mould is dipped into water frequently during use and *sand moulding* is one in which the mould is sprinkled with fine sand or ashes. The object in both the cases is to prevent the sticking of wet bricks to mould. Sand moulding produces cleaner and sharper bricks.

The brick mould is a rectangular box of wood or iron without top and bottom where longer sides project a few cm to act as handles. Seasoned wood is used for the *wooden mould* (Fig. 2.4) and the edges are protected with strips of iron or brass screwed on. *Wrought iron moulds* (Fig. 2.4) are usually used in large brick fields. The advantages of iron moulds over wooden ones are (1) cost less, (2) last longer, and (3)

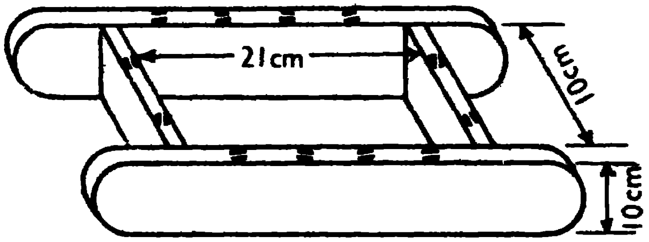


Flan of a brick field

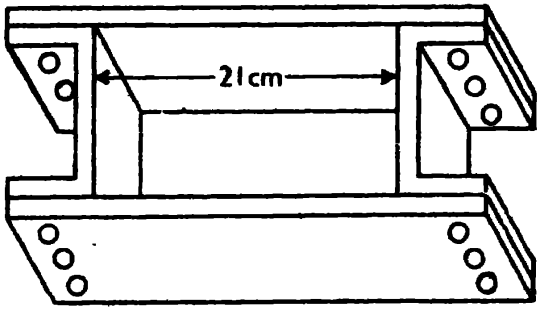


Section of hack on CD

Figure 2.3
Lrick Field



Wooden Mould
Inside dimensions 21X10X10cm are for bricks of size 19X9X9cm allowing for contraction in drying and burning



Wrought Iron Mould
Inside dimensions — 21X10X10cm

Figure 2.4
Wooden Mould

turnout cleaner and more uniform sized bricks. But its only disadvantage is that it wears strikes faster.

Moulds are made a little larger each way say about one tenth of the dimensions of the bricks to be moulded to allow for shrinkage of bricks in drying and burning. The exact allowance to be allowed should be determined in each brick-field by experiment.

In *ground moulding* the moulder places his mould flat at one corner of the ground which is already levelled, plastered and sprinkled with sand. He then lifts a lump of prepared clay over his head with both hands, dashes it into the mould and forces it with hands in order to fill the corners of the mould. He then strikes off the superfluous clay above the level of the mould with a piece of wood or iron called a *strike* (Fig. 2.5.a) or a wire on a bow and throws the cut off clay on the ground to be mixed again with earth to be prepared. The mould is then lifted off leaving the brick on the ground and again placed by the side of the brick thus made. A second brick is moulded then and so on until he moulds bricks lying flat in rows till the whole ground is covered. These are turned on their edges for further drying when they are hard enough to be handled. In this process bricks are made directly on the ground and so their lower faces are very rough and moreover they can have no *frog* or *kick* *

In *table, pallet, or sand-moulding* (Fig. 2.5.a) the moulder stands behind a table and places his mould either on the table itself, in which case the bottom of brick is flat or generally on a board fixed on table called *stock board* (Fig. 2.5.a) of the same size as the inside measurement of the mould and carrying projection for the *frog*. The mould in the last case is to be made deeper than the thickness of brick by 3·75 cm which is the thickness of the stock board. The mould is placed to fit the stock board, filled up with earth, superfluous earth removed as described above, a thin *pallet board* (a wooden board a little longer than mould) is placed on the mould, and then mould, board and brick are lifted together smartly off the stock board inverting it as he does so. He then places the whole on the *page* (Fig. 2.5.a) on his left side with pallet board downwards and lifts up the mould leaving the brick on the pallet board. A boy places another pallet board on the brick and carries it away between two boards to the drying ground where it is placed on its edge. Pallet boards are removed. The 2nd brick moulded

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* *Frog* is the indentation made on one face of brick which often carries maker's initial. Brick is generally laid in brickworks with frog up, which affords a key for the mortar to hold the brick on top.

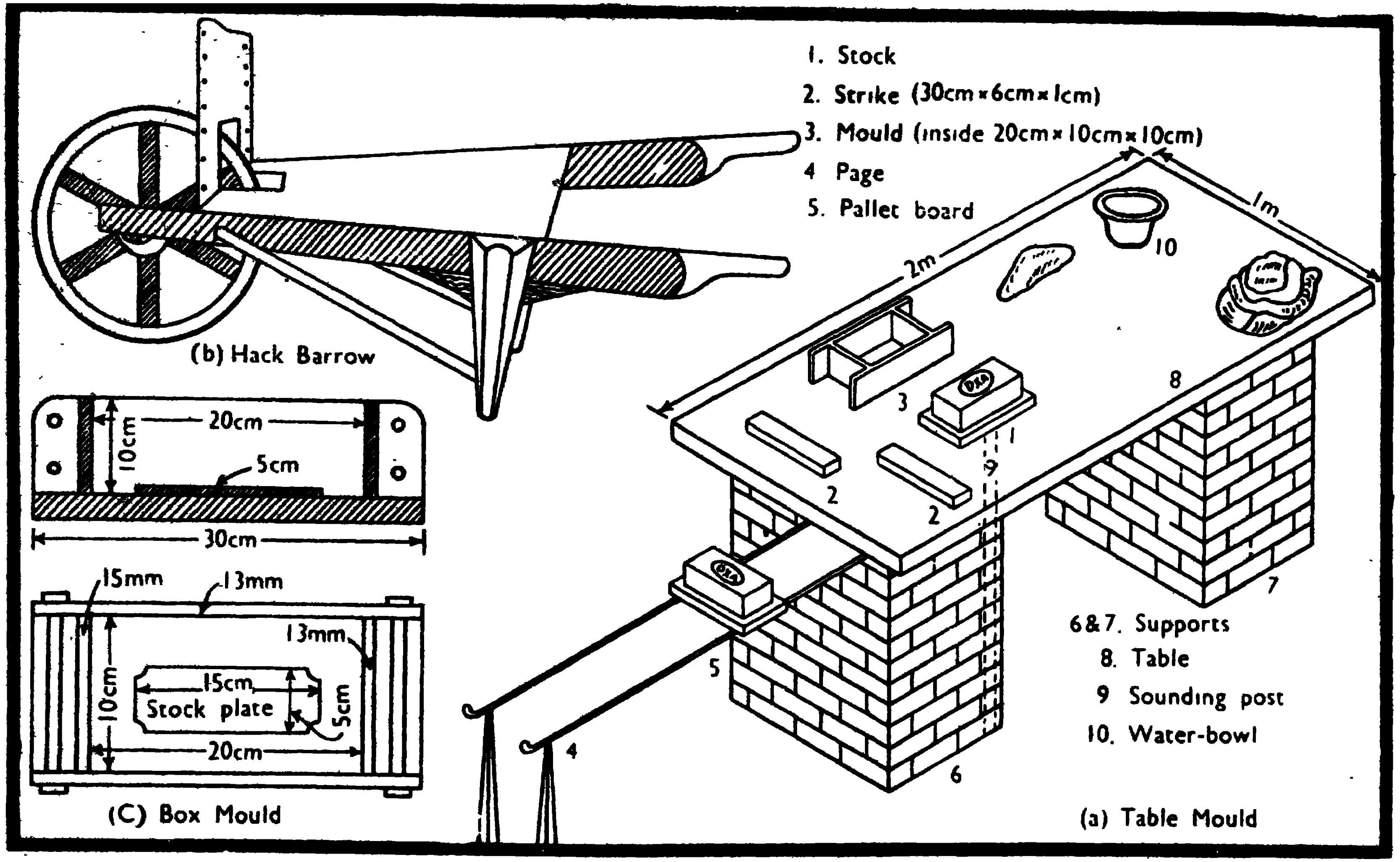


Figure 2.5 Table Moulding

is placed next to the 1st and this is repeated until the whole space is covered. In this case bricks are laid on edges and so less space is required for drying ground and moreover bricks dry better and quicker. *Hack barrows* (Fig. 2.5,b) are often used to carry a number of such bricks to the hack ground of the *brick field* (~~Fig.~~ 2.3) at a time.

**Disadvantages of table moulding—**

1. Various articles, such as table, pallet boards, page, hack-barrows, etc. are required which cause inconvenience to moulders and increased expenditure to brick-layers.

2. Bricks when soft are little out of shape as they are placed on their edges on the hack ground.

3. Moulds without the bottom require well pugged stiff clay

The disadvantages are eliminated by moulding bricks in *box mould* (Fig. 2.5.c) with bottom piece carrying projections for the frog. Bricks are usually made with a frog or hollow in the upper surface to provide a key for mortar joints. Mould without bottom piece is called *sancha mould* (Fig. 2.4).

In *box moulding* the moulder sits near the heap of prepared clay, fills his sand sprinkled mould with the clay, strikes and removes the superfluous clay above the mould and then carries the mould with its filling to the drying ground when he inverts the mould gently tipping the brick earth. He then goes back to the heap and the operation is repeated. 2nd brick is placed next to the 1st and this goes on until the whole ground is covered.

Any sort of clay will do for the mould as in this process the bricks are allowed on their flat faces to dry and harden before they are turned on their edges for further drying. Pugged earth gives better bricks but ordinarily the clay is simply mixed with kodali and laid in heaps. This method dispenses with the services of page-boys and hack barrow-men and no big hack ground is required. Box-mould can be used on tables as well but moulders prefer platforms. A moulder can mould per day about 600 bricks on ground and 1,000 bricks on table on an average.

*Hand moulding* includes *table or ground-moulding*, *slop or sand moulding* and *box moulding*. Bricks can also be machine moulded but this method is seldom used in India.

*Machine-moulding* is advantageous when a large number of bricks

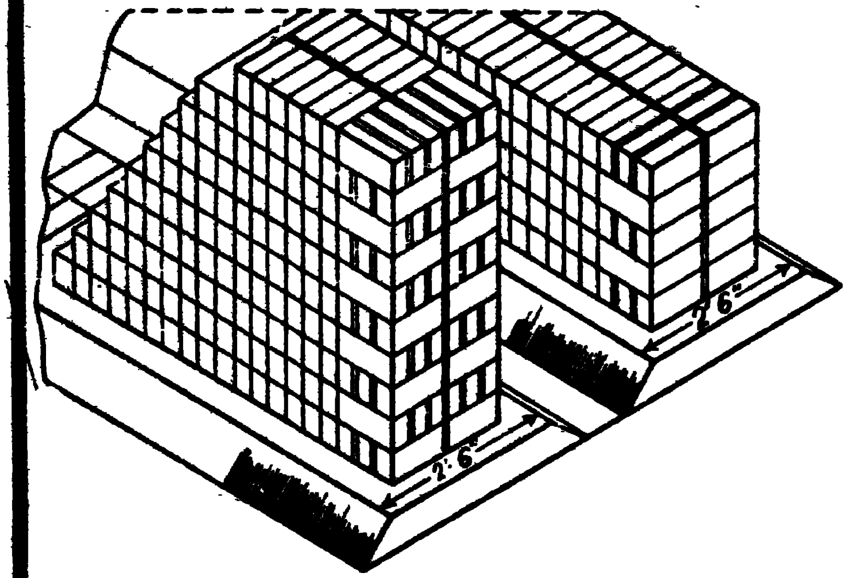


Fig 2.6 Hacks with stacked bricks

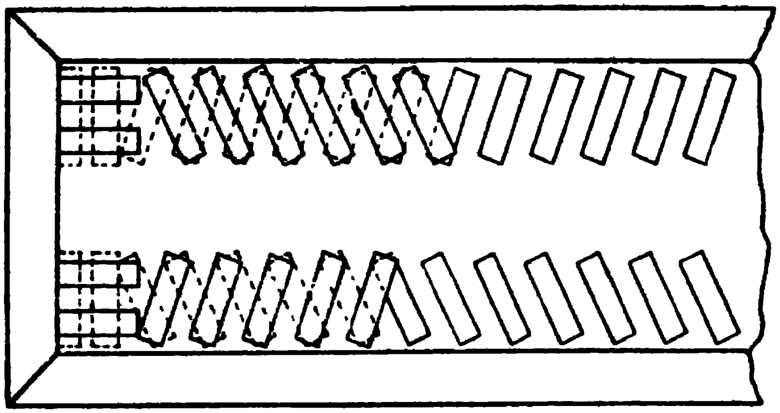
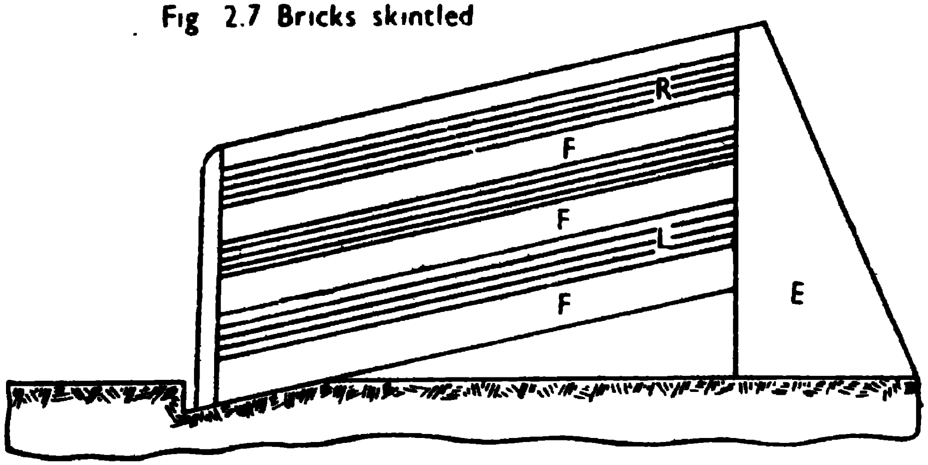


Fig 2.7 Bricks skintled



R - Raw bricks

L - Layers of raw bricks on edge

F - Fuel

E - Earth

Fig 2 8 Brick clamp with wood-fuel

are to be made at the same spot and where clay is very hard and stony. In *plastic clay machines* the pugged clay in a plastic condition is forced through a rectangular opening of a size equal to the length and breadth of the brick, cut into strips of the thickness of the brick with wires in frames and then dried as usual. In *dry clay machines* the dry clay is reduced to powder, filled dry into a mould by the machine and then subjected to a very high pressure into hard and well shaped bricks. These machines are used where a very large number of bricks is to be manufactured within a short time and moreover they produce cheaper and better bricks.

2.8.3 *Drying*. After the moulded bricks have dried on edges they are dried further in stacks. The *hack* (Fig. 2.6) or the drying ground should be raised and sanded to allow any rain water to flow off. Generally the stack is of a breadth equal to two bricks laid longitudinally with a small space between the bricks. The alternate tiers are along and across the stack all on edges and about ten tiers of bricks on edges with intervals between them may be built up. They are then allowed to dry for about 3 days after which when hand hard they are restacked or *skintled* (Fig. 2.7) at an angle with the hack lines with an opening between each brick for thorough ventilation. It takes one to two weeks to dry thoroughly according to weather. The bricks should be in stack until thoroughly dry otherwise heat of clamp or kiln will dry damp bricks suddenly and damages the bricks by splitting or warping.

Brick making is usually suspended during rainy season yet the raw bricks in stacks are to be protected from getting spotted or spoilt in absorbing rain water by out of season shower with durmah matting on top and sides.

The I.S. Code specifies the following for drying of bricks :

(i) The moulded bricks shall be allowed to dry to a approximate moisture content of 5 to 7 per cent.

(ii) As far as possible the moulded bricks shall be protected effecting against rain and dampness till they are stacked inside the kiln.

(iii) During conveyance to the kiln, the moulded bricks shall be loaded and unloaded one at a time.

2.8.4 *Burning*. The burning of dry raw bricks may be done either in a *clamp* or *pazawah*, or in *flame kiln* or *bhatta*.

The flame kiln may be *overground* or *underground*. In India both clamps and kilns are used in burning bricks. In clamps both bricks and fuels are placed in alternate layers and burned in the open air but in kilns bricks are stacked without fuel in a masonry enclosure with or without roof and burned from flues below. The arrangement and shape of the clamp widely vary in different parts of India and there are various types of kilns and so it will not be possible to describe all of them in this book. The knowledge obtained by reading mere description of clamps and kilns cannot be compared at all with that obtained as a result of visits to the actual clamps and kilns during construction and when in working order.

**2.8.4.1** *Clamp burning with wood as fuel* (Fig. 2.8). A sloped floor of trapezoidal shape is prepared at an angle of about 15° from the short end which is in slight excavation but the wider end is raised a little above ground. A layer of fuel consisting of grass, cow-dung, etc. about 1 m thick is laid on the prepared floor as they burn slowly and evenly than wood and over it 4 or 5 courses of bricks on edges with small spaces between them are put. A second layer of fuel is then laid about 15 cm thicker than the layer of bricks followed by another five courses of bricks on edges and so on. The clamp is fired at the lower end when it is built up one-third its full height of 3·5 m with an object of burning the lower part but the top loading will proceed at the same time until it is completed. Then the clamp is plastered over with mud on top and sides to prevent the escape of heat and left to burn and cool itself. Violent outburst of fire anywhere is put down by throwing earth or ashes. This type of clamp is mostly used in Bombay, Uttar Pradesh and Bihar. Wood or coal dust may also be used and the proportion of fuel is gradually reduced towards the top but wood fuel is not good as it burns bricks quickly. Bricks burnt with tamarind wood as fuel burn slowly and are not liable to be attacked with saltpetre. Such a clamp will burn from 20,000 to 200,000 bricks and takes from 2 to 4 months to burn and cool.

*Bengal clamp with coal as fuel* (Fig. 2.9)—The site for the clamp (Pazawah) is first carefully levelled and made firm with a drain dug round it to catch rain water, if any. The bottom of the clamp which is a rectangular in form, is set out to the required size with *live holes*, *wood flues* or *chulas* 30 cm × 35 cm at 2m apart and *air flues* 12 cm × 35 cm running at right angles to each other. Air flue walls consist of 3 courses of brick on edge or 5 courses of brick flat and a brick wide. Burnt bricks are used for the base and casing if available and the quantity will be about 12% of the bricks to be burnt in the clamp. Chulas are filled up with dry split up wood. Two courses of flat bricks are then laid over air flue walls and chulas to make a level floor for

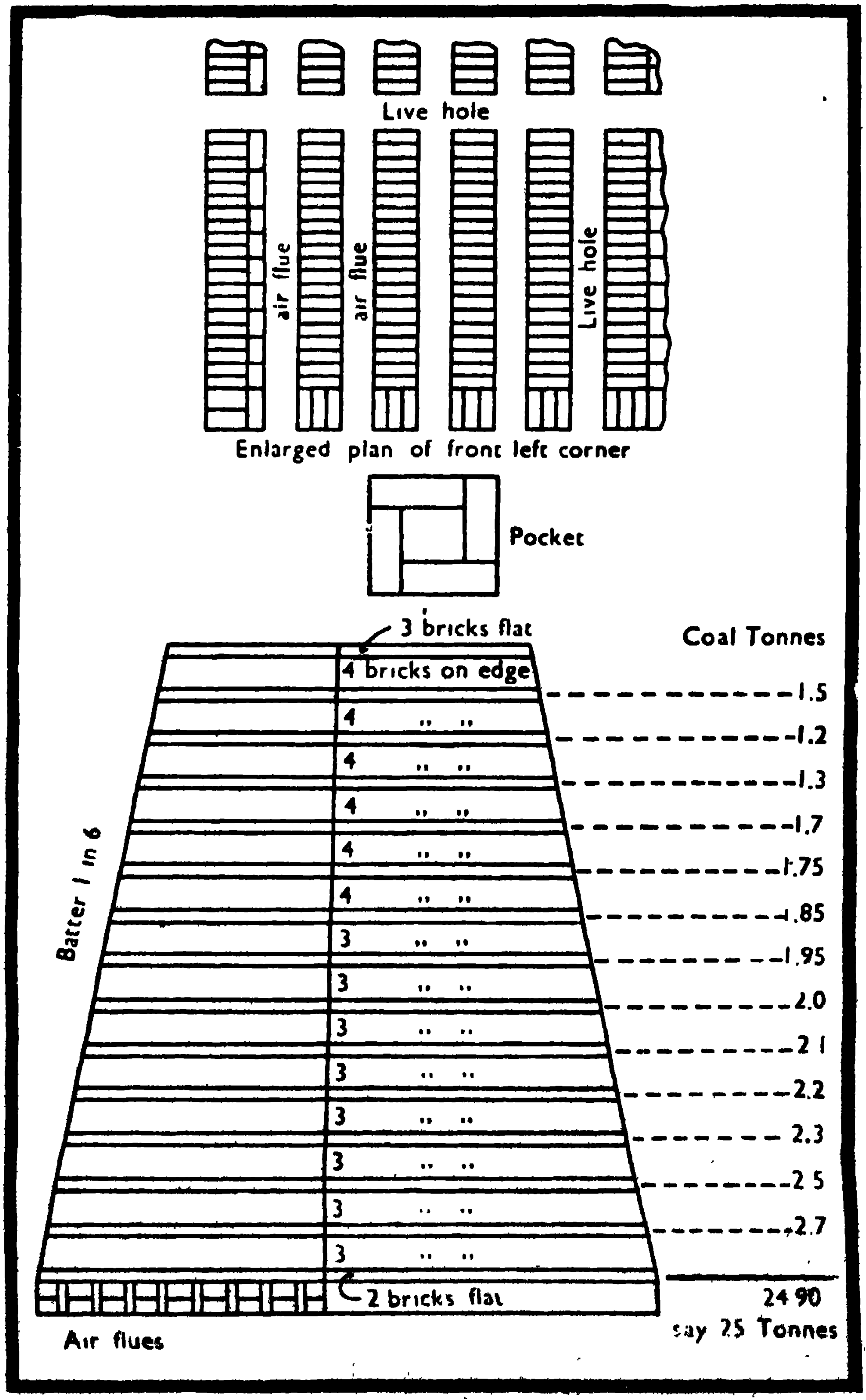


Figure 2.9 Sectional Elevation of a Bengal Bricks Clamp with coal as fuel

the first layer of coal. The rubble coal for the bottom layer should be about 5 cm cubes but fine screenings are for top courses. The bottom course of coal is levelled and over it two courses of raw dry bricks are stacked on edge by experienced men and then another layer of coal and so on until bricks and coal in alternate layers reach to the desired height gradually tapering towards the top. Over the top most layer of fuel 2 or 3 courses of raw dry bricks are laid flat with a 10 cm earth or rubbish topping so as to prevent the escape of heat and also to protect it from rain to some extent. This process of stacking bricks in a clamp is known as *setting*. All chulas are fired and the fire is kept up until the wood in chulas is ignited, then the mouths of chulas are stopped with bricks and plastered over with clay. The sides are either encased by a layer of bricks in mud with mud plaster on the top or simply plastered over with mud.

If proper precautions are taken in setting the clamp and burning, then there will be an out turn of 57% of 1st class bricks, 20% of 2nd and 3rd class bricks, 3% of picked Jhama, 10% of Jhama bats and 5% of brick bats. A greater % (80 %) of 1st class bricks are prepared without further expenditure by putting coal in *pockets* (Fig. 2.9) throughout the height of the clamp. The last layer of raw dry bricks on edge in the various courses in clamp can be arranged in pockets, instead of being packed close. This arrangement also prevents settlements due to the fuel being burnt into ashes and protects fuel from wind. The quantity of rubble coal required for one lac of bricks is about 25 tonnes.

**Advantages of coal used as fuel—**

1. The thickness of coal in different layers in the clamp is less and so it will sink less, wind is better kept and breakage is less than the wood clamp.

2. It is economical where coal is cheap and the percentage of out turn is greater than the wood clamp.

**Advantages of clamp burning—**

1. It is economical. 2. This system is well understood by the uneducated brick burners. 3. The clamp bricks are tougher than kiln bricks due to gradual burning and cooling.

**Disadvantages of clamp burning—**

1. It is a very slow method. 2. Regulation of fire is not possible. 3. Out turn of bricks is not quite uniform. 4. Large portion of

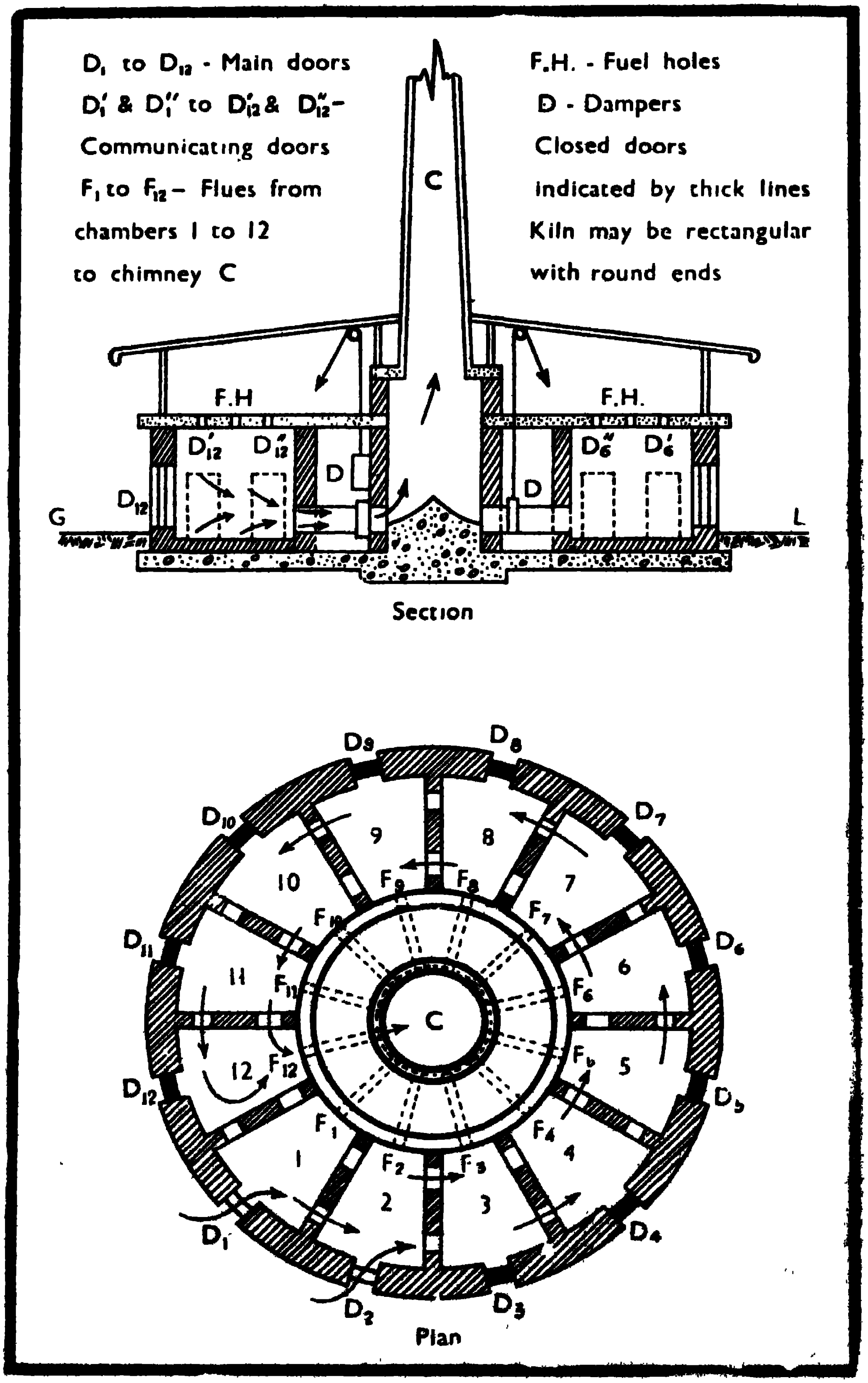

D1 to D12 - Main doors
D1' & D1'' to D12' & D12'' - Communicating doors
F1 to F12 - Flues from chambers 1 to 12 to chimney C
F.H. - Fuel holes
D - Dampers
Closed doors indicated by thick lines
Kiln may be rectangular with round ends
C
F.H
F.H.
D12'
D12''
D
D12
G
D
D6''
D6'
L
Section
D9
D8
D10
D7
9
8
10
7
F9
F8
F10
F7
D11
D6
11
F11
6
F6
C
12
F12
F5
5
D12
D5
F1
F4
1
F2
F3
4
2
3
D1
D4
D2
D3
Plan

Figure 2.10 Hoffman's Kiln

bricks is distorted and cracked while soft and hot due to their settlement when the fuel at the bottom is burnt to ashes.

**Sizes of some clamps at base**

| Base area of clamp $m^2$ | Bricks burnt in lacs | Time required to burn and cool in months |
|---|---|---|
| 10m × 10m | 1 | 1½ |
| 16m × 16m | 3½ | 2½ |
| 22m × 22m | 7½ | 3½ |

**Empirical rule for determining the number of bricks in a clamp—**

Approximate number of bricks in a clamp in lacs

$$= \frac{\text{Base area of clamp in m}^2}{75}.$$

2.8.4.2 *Flame Kiln.* The flame kiln may be intermittent or continuous kiln and it may be either **overground** like **Sind** or **Allahabad kiln** or **underground** like the **Bull's trench kiln.**

*Hoffman's Kiln* (Fig. 2.10) is an overground continuous kiln. It is circular in plan and is divided into a number of chambers, each provided with a door for loading and unloading and a flue with a damper for controlling the inflow of air and another flue on the inside connected to the central chimney. The flue can also be opened or closed by means of a damper. A kiln with 12 chambers is found most convenient in practice. The moulded bricks are stacked into the chambers and ten compartments (No. 3 to 12) would be full but No. 1 & 2 would be in the process of loading raw bricks and emptying cooled down burnt bricks respectively. No. 3, 4, 5 & 6 contain bricks which have been burnt and are cooling down. No. 7 & 8 contain bricks which are being supplied with flue from the fire holes. No. 9, 10, 11 & 12 are getting dried and preheated. Thus a continuity of operation is maintained, namely, receiving raw bricks, drying them, heating, burning, cooling and emptying. The circulation of the flue gases through the kiln is as follows :—Cold air enters to No. 1 & 2 through the open doors and enters into cooling chambers No. 3, 4, 5 and 6 and then passes in a heated condition into burning chambers No. 7 & 8. The hot flue gas passes in continuity to chambers No. 9.

10, 11 & 12 for pre-heating the raw bricks. Each chamber if made about 9 m × 3·5 m × 2·5 m will hold about 20,000 bricks per day.

2.8.4.3 *The overground intermittent kiln* (Fig. 2.11) is a rectangular building about 6 m × 4 m with opening at the top and doorways at the ends. Length of the kiln will depend upon the quantity of bricks to be burnt.

There are several openings in walls opposite to one another. Trenches 40 cm × 35 cm are dug across the floor with 1 m spaces (rouses) between them. Bricks to be burnt are stacked on edge on these spaces with a little space between them through which fire can find its way to and around every brick. The 8th, 9th and 10th courses are corbelled to span over the trench and form the flues to contain fuel. The remaining portion of the kiln is then filled up with kutcha bricks on edge with narrower spaces between them towards the top and also 10 cm thick earth is spread over topmost layer of bricks to prevent the escape of heat. Arch openings opposite flues are left in side walls for introducing fuel wood. The ends are built up and plastered over with clay when the kiln is filled up with dried brick. At first the fires are kept low in the arch openings to drive off the moisture and dry the bricks thoroughly. After about 3 days the fire is allowed to burn brightly and the heat is regulated by regulating the supply of fuel and air. The air can be regulated by raising or lowering the dampers (sheet metals) at the arch opening of side walls. Bricks during burning can be watched through arch openings. In 2 or 3 days the bricks will be sufficiently burnt and will settle down to some extent. Openings are plastered over with clay and the kiln is allowed to cool for about 10 days before the bricks are withdrawn or unloaded from the top of the kiln and then it can be reloaded again from the top. It may be in two parts where one part may be burning and cooling, the other may be unloaded and reloaded.

The progress of fire can be studied by watching the top of the kiln. While smoke comes out as long as there is moisture in the bricks, dark smoke comes out when bricks are dry and burning is complete when the kiln sinks by few inches. Three kinds of bricks are obtained from the kiln. Lower courses are burnt to hardness, the middle courses are well burnt and the top courses are under burnt.

The disadvantage in this kiln is that heat escapes when topmost bricks are burnt and so there is waste of fuel and increased cost of manufacture. This defect is removed in Bull's trench kiln, which is used in India for brick manufacture on a large scale.

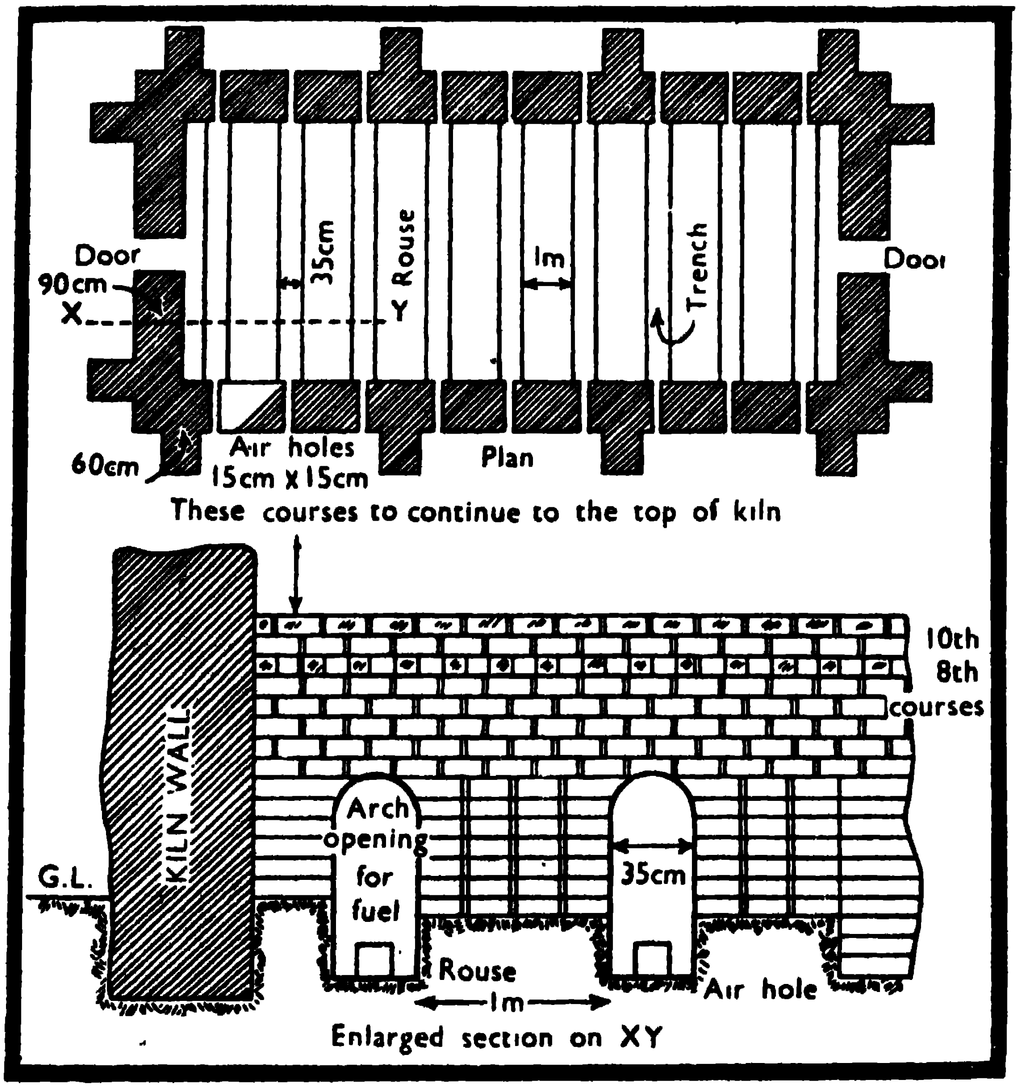


**Figure 2.11 Overground Kiln**

**2.8.4.4** ***Underground continuous kiln, trench kiln, or Bull's trench kiln*** (Fig. 2.12). It is rectangular, circular or oval in plan, 6 m×2 m. The length of the kiln depends upon the site available and the number of bricks to be manufactured. The most common shape of the kiln is an oval one with semi-circular ends to save space but in this case irregularity of burning results as firing approaches or leaves semi-circular ends. Uniformity of burning results in a circular section and the second best is the rectangular section. It is made in a trench excavated below ground and lined with masonry walls. A number of openings are built around the outer walls of the kiln and movable iron chimneys are placed over the openings ·8 m×·3 m×2 m at about 3·5 m apart and the coal pits lie between them. These chimney openings (Fig. 2.3) are connected to the trench by two arched openings for draught. Sometimes permanent chimneys are built over these openings but for economy

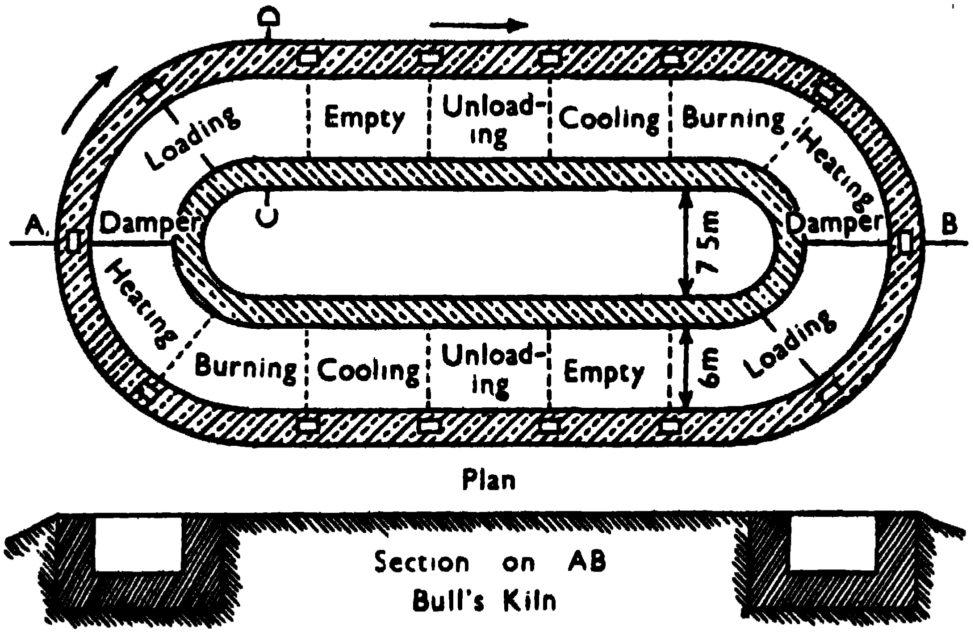


Figure 2.12 Bull's Kiln

movable iron chimneys on four wheels can be used by easily moving them along the kiln. In some cases chimney openings are provided in the inner wall as well but in others chimneys are placed over the arranged bricks in the kiln and in that case no hole is to be provided in the walls. Dampers or iron plates are placed by the side of these openings. The space between two dampers in the trench is called a section. Each section of a trench of 5·5 m width contains 10,000 bricks which require 1·6 $m^3$ of coal to burn. A section of 7·5 m width contains 14,000 bricks or 2·25 quintals of coal dust are required per 1,000 bricks. ⅔rd of these bricks are 1st class bricks. Fig. 2.12 is an oval trench kiln in which loading, drying, burning, cooling and unloading take place in two stages. Two chimneys and two batches of men are required for it. The arrows on plan indicate the direction of the movement of chimneys.

One section is loaded first and then covered with earth on top to prevent the escape of heat. When one section is being burnt its hot gases pass on to the next section to warm up the bricks already stacked in the 2nd section before passing out through the chimneys. When 1st section is burnt and the fire has advanced to the next all flue holes of the 1st are closed and it is allowed to cool gradually. When fire has advanced through a number of sections from one side, the 1st section cools sufficiently and is unloaded and reloaded with dry raw bricks which in their turn are warmed up first with the hot gases of the last section and then burnt by the advancing fire going round the kiln. The kiln works continuously admitting of loading, drying, burning, cooling and unloading to go on simultaneously in the different sections.

**2.8.4 5** *Setting the kiln.* The setting is shown in Fig. 2.14. There are 18 layers of bricks of which the lower 15 layers are on edge and upper three layers are flat. 4th, 6th, 9th, 11th and 14th layers are spanners. A little space should be left between the bricks when loading except those spanning the combustion chambers. These spaces should not be less than 2 cm in the bottom courses decreasing to $\frac{1}{2}$ cm in the upper ones. The bottom course will always be 2 bricks-on-edge under each wall of raw bricks 5 cm apart. Any damper-space may be taken as the starting point. There are 5 combustion chambers to each damper length. As each chamber is loaded it is to be covered with brick flat in breaking joints except over the combustion chambers. The feed holes are then formed over the combustion chambers. Over each of the two outer green brick walls there should be a feed hole and after that over every alternate wall. Earth is then evenly spread to the level of the top of the bricks temporarily placed over the feed holes. 15 cm space is provided for lowering the cross damper from top to bottom. The 1st damper-length having been set, every successive one is precisely the same. Four damper lengths having been loaded, the necessary arrangement may be made for firing.

The I.S. code lays down the following for setting of bricks :

(i) Pave floors with burnt bricks.

(ii) Set the bricks in uniform pattern.

(iii) The top two courses of katcha bricks in the kiln, should be set as close together as possible with little or no spacing between them.

(iv) The top of setting excluding portion occupied by fixed holes should be covered with a fire ash about 20 cm thick. The fixed holes should be tightly closed with C. I. covers.

**2.8.4.6** *Firing the kiln* On starting firing, rubble coal is placed on the grating of the temporary furnaces at the commencement of each section and ignited by wood fuel from below and this is called ***bottom firing***. About 15 quintals of wood is needed for igniting the furnace at the start. Chimney is placed over the hole in the 3rd section in front of the temporary furnaces and two damper lines behind the chimney are used as shown in Fig. 2.12 Firing is continued for about 6 hours in this way and then furnace openings are closed up with bricks. Rubble coal is now poured in through the feed holes at the top of temporary furnaces and after about 36 hours bricks at the bottom become red. Then coal dust is introduced from the top and this is known as *top firing*. The quantity of coal dust required per 1,000 bricks is about 0·25 tonne.

*Use of chimney and damper*—Temporary damper is placed 4 hours after the chimney is placed. Damper is gradually lowered. When the bottom layers of bricks of the 6th line from chimney are red then the iron plates of the damper in the 1st position are removed to the 3rd behind the 2nd and placed in position from side walls to the centre of trench. All holes for the escape of air are closed and the chimney is shifted to the next chimney hole but in that case previous chimney hole is closed as well.

*Perfect burning*—Five bricks flat are firmly embedded into the earth spread over the kiln between each line of feed holes at equal distances and their surfaces should be on a level with the top of a brick flat placed on each wall of the kiln in the same line. The sinking of these five bricks below the level of the two bricks on kiln walls will indicate the settlement and it can be tested by a strong cord. The amount of settlement for perfect burning is 5 cm depending on the trench and the nature of clay.

*Unloading the kiln*—Unloading is done in the 1st section when bricks in 12 sections are burnt. Cold air enters the trench during unloading bricks after removal of earth on the top. Bricks cool suddenly and so these are brittle. A line of dampers called *back dampers* must be placed behind the unloading section so as to prevent rapid cooling.

**Average out turn of Bull's trench kiln**

| | | |
|---|---|---|
| 1st class bricks | — | 65% |
| 2nd ,, ,, | — | 10% |
| 3rd ,, ,, | — | 10% |
| Picked jhama | — | 5% |
| Jhama bats | — | 5% |
| Brick bats | — | 5% |

The smallest size kiln of 20 chambers and of 5·5 m width with one chimney will turn about 10,000 bricks daily and about 18 lacs per session. A larger size kiln of 24 chambers worked by two chimneys will be economical to work and cheaper in construction. In 40 chambers kiln two burnings may be carried on at the same time but kiln of 20 chambers being sufficient for a single burning.

**2.8.4.7** *Approximate dimensions of the Bull's trench kilns of three sizes* :

| No. of kiln | Radius in metres | | Width of kiln | No. of Chambers | Length of chambers in inner walls | Length of feed hole inner wall | Out turn in lacs in one session | Length of chimneys (metres) | |
|---|---|---|---|---|---|---|---|---|---|
| | Outer | Inner | | | | | | Outer | Inner |
| 1 | 17 | 12·5 | 4·5 | 20 | 4·00 | ·80 | 18 | 10·5 | 0 |
| 2 | 22 | 14·5 | 7·5 | 24 | 3·75 | ·80 | 30 | 10·5 | 7 |
| 3 | 43 | 27 | 7·5 | 40 | 3·80 | ·80 | 65 | 10·5 | 9 |

Bull's trench kiln with built chimneys is also made to save all troubles in moving chimneys and anxiety in rough weather.

I.S. 2117-1967 : Specifies the following regarding firing, its control and cooling.

(a) *Starting kiln firing* :

(i) The number of chamber on a continuous kiln that are initially "set" for starting the kiln should not be less than three.

**Note :** In Indian practice, the chamber normally has six rows.

(ii) The place fixed for starting the fire should be separated from the space occupied by the brick "set in the kiln".

(b) *Control of burning* :

— (i) Fuel feed : Bulk of the slack coal shall be below 15 mm.

(ii) Fuel shall be fed directly to the chamber through feed holes only, when the brick and the kiln floor have been heated over 700°C. The fuel should be fed in small quantities at regular interval. Feed holes should be covered tightly after every feed.

(c) *Control of temperature*

750°—1000°C depending upon the type of clay.

**Note :** Either a pyrometer or pyrometria cones whichever is suitable may be used for measurement of the temperature. Rate of fire travel should not be less than 50 m. per 24 hours.

(d) *Draught Control* :

Draught should be adjusted by operating the dampers.

(e) *Stages in Firing cycle* :

(i) Smoking, (ii) Pre-heating, (iii) Firing, (iv) Soaking, (v) Cooling.

**Note** : If the temperature gradient covering all the above distinct stages is studied, and a graph drawn, it will approximately follow the familiar patterns of a parabolic curve.

(f) *Cooling* :

Cooling of the brick in the kiln should be gradual and should allow the minimum period required by the designs of the kiln.

**Note** : For proper inspection of the quality and count of bricks, they may be stacked in stacks, two bricks and ten courses high and hundred bricks long, the distance between two adjacent stacks being not less than ·8 m.

2.8.4.8 *Method of distinguishing clamp burnt, kiln burnt and machine made bricks.* Traces of breeze mixed with clay are generally seen in clamp burnt bricks. Kiln burnt bricks are mostly uniform in colour and machine made bricks are distinguished by wire marks, frog on both sides or letters on their surfaces.

**Comparative merits and demerits of clamp and kiln burning**

| Points of comparison | Clamp | Overground kiln | Underground kiln (Bull's trench kiln) |
|---|---|---|---|
| 1. Initial cost. | Least, as no masonry structure is to be built. | Intermediate, as the rectangular enclosure with old bricks is to be constructed. | Greatest, due to the construction of masonry structures below ground but cheapest ultimately for the production of large number of bricks say over 5 lacs. |
| 2. Cost of fuel. | Least, as straw, cowdung, etc. may be used. | Greatest, as heat is wasted from top and moreover wood is used as fuel. | Intermediate, as there is no wastage of heat, from top but hot gases are utilised to warm up the kutcha bricks before escaping through the chimney though wood or coal dust is used. |

| Points of comparison | Clamp | Overground kiln | Underground kiln (Bull's trench kiln) |
|---|---|---|---|
| 3. Labour. | Supervision is not necessary once started and fired. | Skilled supervision is necessary during setting up and firing. | Skilled supervision is continuously necessary as the process is a continuous one. |
| 4. Fire regulation | Fire cannot be regulated. | Fire can be regulated from the beginning to the end. | Fire can be regulated throughout. |
| 5. Quality of kutcha bricks to be burnt. | Kutcha bricks to be burnt must be perfectly dry otherwise sudden heat will crack and warp them. | Bricks in slightly moist condition may be loaded, as fire is kept low at first to dry them. | Moist kutcha bricks even can be burnt with safety as they undergo a process of warming first. |
| 6. Effect of wind. | Greatly effected by wind and weather as it has got no enclosure. | Less effected by wind and weather as it is opened at top with enclosure on four sides. | Not effected by wind and moderately bad weather as it is constructed below ground level and covered with earth on top. |
| 7. Time of burning & cooling. | 2 to 6 months according to sizes. | 3 to 4 days for burning and 10 to 15 days for cooling. | 1 day for burning and 10 to 12 days for cooling. |
| 8. Quality. | Not uniform in quality and colour due to non-regulation of fire. Tougher as the bricks cool slowly. | Uniform in quality and colour due to moderate regulation of fire, comparatively brittle as the cooling is more rapid. | Most uniform in quality and colour due to better regulation of fire. Brittle as cooling is rapid. |
| 9. Average outturn of 1st class bricks or good bricks. | 60 per cent, as bricks are liable to injury due to settlement of bricks when fuel is burnt to ashes. | 70 per cent, as bricks are liable to injury to some extent. | 80 per cent, as the bricks are less liable to injury. |
| 10. Suitability. | Most suitable when bricks are required in small numbers and not at once, due to initial cost and time for burning and cooling. | Intermediate. | An assured supply can be counted upon as some bricks are burnt daily and so it is most suitable when bricks are required continuously in large numbers as it is a continuous process and moreover initial cost will be high for small numbers. |

**Comparison of the cost of manufacture of a lac of bricks in clamp and Bull's kiln (Bengal)**

| | *Clamp* | *Bull's kiln* |
|---|---|---|
| Earth digging 300 cu. m. @ Rs. 2/- per c.m. Rs. | 600/- | Rs. 600/- |
| Sand ... ... ... | 150/- | 150/- |
| Moulding, temping, drying, setting raw bricks in clamp or kiln, unloading, sorting and stacking @ Rs. 30/- per ‰ | 3000/- | 3000/- |
| Rubble coal 25T @ Rs. 80/- per tonne | 2000/- | |
| Fire wood 1·5T @ Rs. 60/- per tonne | 90/- | |
| Steam coal 10T @ Rs. 80/- per tonne | ... | 800/- |
| Coal dust 25T @ Rs. 60/- per tonne | ... | 1,500/- |
| Firing, labour, repair, etc. | ... | 200/- |
| Rs. | 5840/- | Rs. 6250/- |

OUT TURN

| | | | *In clamp* | *In Bull's kiln* | |
|---|---|---|---|---|---|
| 1st class bricks | 55% | @ Rs. 83/- per ‰ = | Rs. 4565/- | 75% = | Rs. 6225/- |
| 2nd ,, ,, | 10% | ,, ,, 80/- per ‰ = | 800/- | 10% = | 800/- |
| 3rd ,, ,, | 12% | ,, ,, 70/- per ‰ = | 840/- | 10% = | 700/- |
| Picked ,, | 3% | ,, ,, 80/- per ‰ = | 240/- | 2.5% = | 200/- |
| Jhama bats | 10% | ,, ,, 60/- per ‰ = | 600/- | 2.5% = | 150/- |
| Brick ,, | 5% | ,, ,, 55/- per ‰ = | 275/- | ... | ... |
| Wastage | 5% | ... ... | ... | ... | ... |
| Rs. | 100% | Rs. | 7,320/- | 100% | Rs. 8075/- |
| | | Profit | 25·34% | Profit | 29·2% |

## 2.9 Sizes and weights of bricks

Bricks are made of various sizes according to the custom of the country or whims of the makers and purchasers but in all cases the length should be double the width plus the thickness of one vertical joint so that one stretcher along the wall will just cover two headers placed across it with a joint between them. The sizes of bricks also should be such that when wet they can be lifted easily and placed with one hand and that they can also be easily burnt to the core.

It was found to be difficult to burn large bricks such as old Indian bricks (25 cm × 15 cm × 6 cm) thoroughly and moreover it was too large to be handled by brick layers with one hand. So they are reduced in size for ready manipulation with left hand leaving the other free for trowel. Smaller bricks such as jafri bricks (10 cm × 7·5 cm × 2·5 cm) take more mortar as the number of joints are more though they are easy to burn and so they are expensive and require more labour.

**Standard sizes of bricks in cm—**

19 cm × 9 cm × 9 cm
19 cm × 9 cm × 4 cm

## 2.10 Classification of bricks

Well burnt bricks are classified

(a) *First class bricks*
(b) *Second class bricks*
(c) *Third class bricks.*

The over burnt bricks are classified as 'JHAMAS' whereas the under burnt bricks are called 'PILAS'. Both these qualities are rejects of the kiln.

## 2.11 Characteristics of different kinds of bricks

Specification for different types of bricks are as below :

(a) *Ist class bricks* :

(i) shall be of rectangular shape with well defined and sharp edges and uniform in size.
(ii) shall have clean and even surface but not very smooth.
(iii) shall be perfect, free from cracks, flaws or lumps of any kind.
(iv) on being fractured, the interior surface shall show a uniform and compact texture.
(v) shall be well burnt and shall not be scratched by a finger nail.
(vi) on being struck against another brick of the same type, it shall give a metallic sound and shall not break.

(vii) on being immersed in water for 24 hours, the absorption shall not exceed 16 per cent of the dry weight.

(viii) The crushing strength shall not be less than 105 kg/cm$^2$.

(b) *2nd class bricks* :

(i) shall be of rectangular shape with well defined and sharp edges but slightly irregularity of sizes as can be covered in the courses may be permitted.

(ii) the surface shall be clean but small irregularity may be accepted.

(iii) shall be perfect and free from cracks. However slight chips and flaws may be permitted.

(iv) absorption in weight shall not exceed 22%.

(v) crushing strength shall not be less than 70 kg/cm$^2$.

(c) *3rd class bricks* :

(i) may be slightly over burnt or under burnt, otherwise hall be as second class bricks.

(ii) it need not be of uniform section and may be distorted.

(iii) on being soaked in water for 24 hours, absorption shall not exceed 24%.

(iv) when struck against brick of the same type, it shall give a dull sound.

Over burnt bricks are known as Jhamas. They are irregular in shape and size. The excess burning makes it dark coloured and brittle. Sometimes due to the fusion caused by over-burning, large irregular hard masses are formed. Such bricks are not used in normal Engineering Works but picked Jhamas have been found useful for road soling and concrete aggregate or as road metal.

## 2.12 Use of different kinds of bricks

1st class bricks are used for all sound works of a permanent character and also in face work of structures which are to be pointed. Second class bricks are used mostly in unimportant structures when the bricks will be hidden from view due to plaster and other causes. Third class bricks and kutcha bricks are used in a structure of a temporary character and in places not subjected to heavy showers of rain. Jhama bricks are used for making aggregate of concrete used in structures and also as road metal. Picked jhama or jhama bricks are used for soling of floors and roads. Porous jhama is not at all used in engineering works as it is very light.

## 2.13 Strength of bricks

The crushing strength of hand moulded bricks is 400 to 700 tonnes/m² depending on the nature and proportion of clay but pressed and machine moulded bricks are much stronger as they are made of well pugged clay. The tensile strength of hand moulded bricks is about 200 tonnes/m² and they are not subjected to tension. Shearing strength and transverse strength of bricks are respectively 10% and 13% of their crushing strength. Bricks are not subjected to tensile and transverse stresses in practice for stability.

The strength of brickwork usually depends on that of mortar and not so much on that of bricks. Brick-work in lime mortar (1 lime : 2 sand) can safely sustain a pressure of 30 tonnes/m² but a safe pressure of 100 tonnes/m² can be allowed on cement brick-work (1 cement : 3 sand).

I.S. 1077—1957 specifies the strength of the brick as below :

> Brick shall have a compressive strength of 35 kg/cm². Bricks with compressive strength of above 140 kg/cm² are graded as AA and those having compressive strength between 70—140 kg/cm² are graded as A.

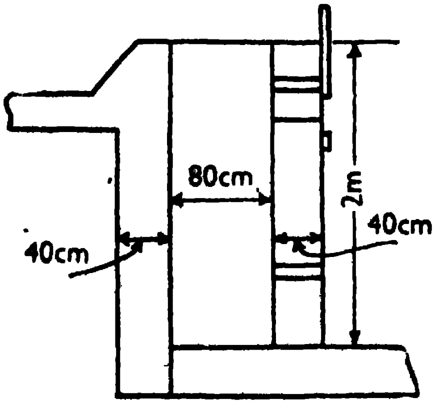


Figure 2.13
Hole below chimney in outside wall

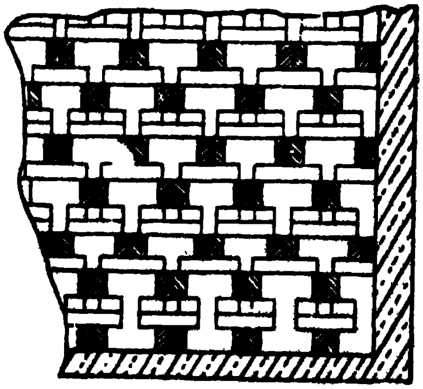


Figure 2.14
Section on CD setting the kiln

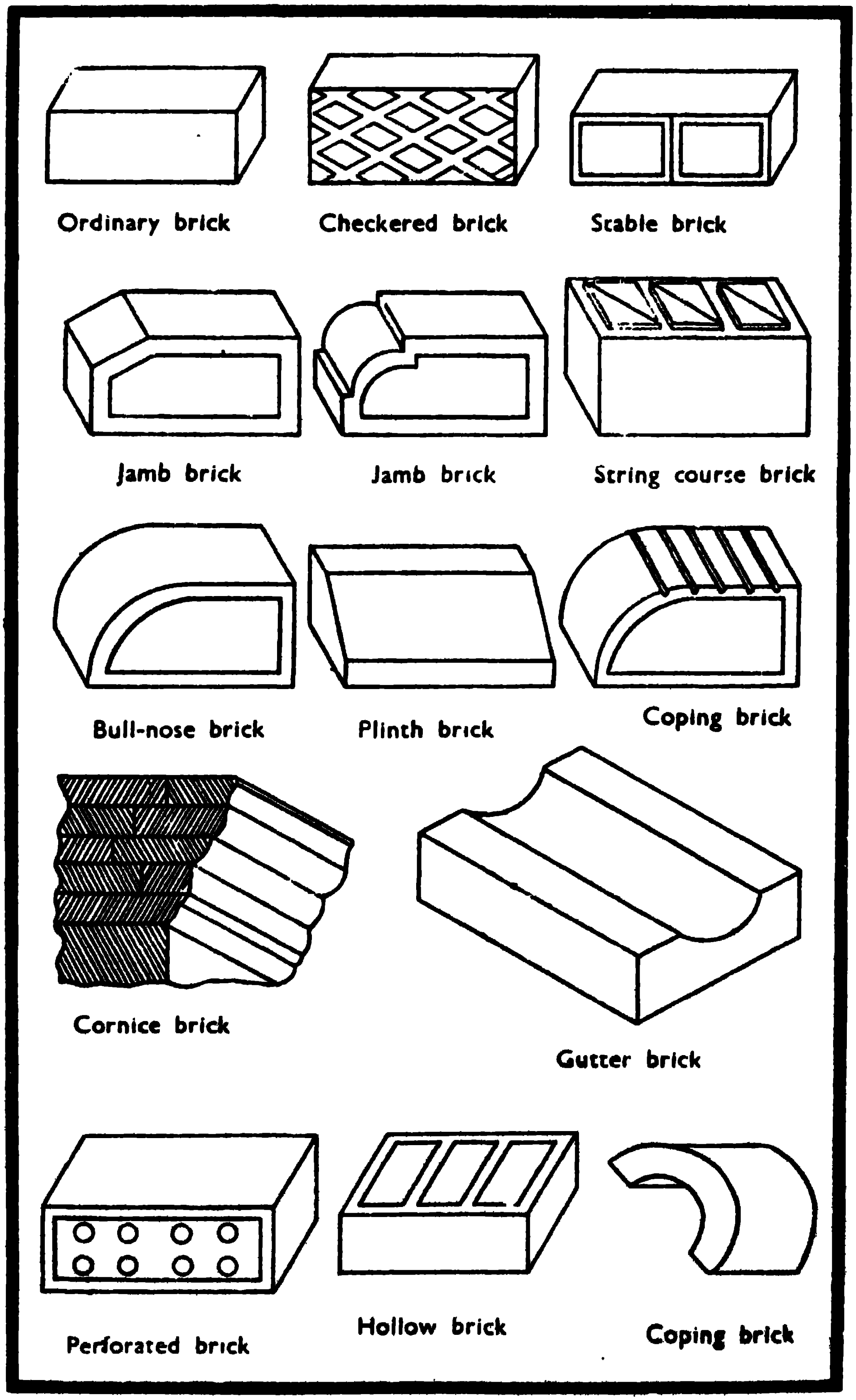


Figure 2.15 Special forms of bricks

### 2.14 Quality of good bricks

The quality of a brick depends on the (a) chemical composition of clay, (b) preparation of clay, (c) kind of fuel used in burning, (d) care taken in moulding and drying, and (e) degree of burning.

The qualities required in good bricks to be tested are as follows—(1) regularity of form, (2) uniformity of size, (3) uniformity in colour, (4) uniformity in texture, (5) soundness, (6) hardness, (7) absorptive power, (8) strength, (9) resistance to weathering, and (10) fire resistance.

### 2.15 Special forms of bricks (Fig. 2.15)

Bricks are usually made rectangular but they are also in various special forms to meet the different situations where they are used and also to suit to the taste of the designer. Such bricks are called purpose made bricks, and are more costly than ordinary bricks. *Paving bricks*—plain or chequered, *stable bricks* with grooved pannels, *jhamb bricks*, *string course bricks*, *bull nose bricks*, for rounding off sharp corners, *plinth bricks*, *coping bricks*, *cornice bricks*, *gutter bricks*, *circle bricks*, *arch bricks*, *perforated bricks*, *hollow bricks*, etc. are some of the special forms of bricks used. Such bricks do away with the cutting of the surface skin of ordinary bricks which cannot thereby stand weather well. Moreover the cost of cutting and other incidental charges and wastage are saved.

### 2.16 Classification of bricks according to moulding

The methods of moulding give rise to the following :

*Soft clay bricks* are either hand moulded or machine moulded from clay made soft by water.

*Stiff clay bricks* are machine moulded from stiff clay.

*Pressed bricks* are moulded from dry or semi-dry clay

*Slop bricks* are made by slop-moulding process.

*Sanded bricks* are made by sand-moulding process.

### 2.17 Fireclay and firebricks

*Fireclay* or *refractory clay* is nearly pure hydrated silicate of alumina ; the greater the percentage of alumina the more refractory the clay will be. It must be practically free from lime, oxide of iron or other substances which tend to melt the clay at a low temperature. These should not exceed more than 5% at any rate. Course and open gained fireclay is preferable to close and even grained one. It can resist high temperature. It is used in the manufacture of firebricks, drain pipes, chimney pots, crucibles, kiln lining etc.

*Firebricks* are bricks made of fireclay. They should conform to the following :—

(i) Shall be capable of withstanding high temperature.

(ii) Hot gases and slag shall not have any action on them.

(iii) When hot, shall be capable of withstanding abrasion.

(iv) Shall have low coefficient of expansion and contraction

**2.17.1.** *Classes of Refractory Bricks* :

(a) Acid Bricks (b) Basic Bricks (c) Neutral Bricks.

(a) *Acid Bricks* :

(i) *Blue bricks* are made from clay and marl which contains 7 to 10% of oxide of iron. These are durable, impervious to water and can resist pressure. These are mostly used for lining the interior of built-up sewers.

(ii) *Fire bricks* are made of fire clay. Fire clay is dug out, weathered, burnt in cupolas or in special kiln at a slowly increasing heat until it attains a very high temperature and cooled gradually. Fire bricks are usually white or yellowish white in colour and are of several varieties. The first class fire brick is capable of withstanding 1700°C and its crushing strength at 1350°C is 2 kg/cm$^2$.

*Silica bricks* are made by grinding up fine pure silica rock and mixing about 1% of milk of lime with it. It is then pressed into moulds, dried and heated for about a week. A cement of same material is used in setting these silica bricks. These silica bricks can resist extremely high temperature upto 1800°C without softening and so these are used as acid lining in Sieman's steel furnace or Bessemer converter where firebricks made from ordinary fireclay cannot stand the temperature of these furnaces. Its compressive strength is upto 150 kg/cm$^2$

*Sand-lime bricks* are bricks made from an intimate mixture of sand and hydrated lime of required quality, moulded under mechanical pressure and subjected to steam under pressure in a closed chamber. These are usually white in colour and sometimes tinted due to the colour of sand in it but they are coloured by mixing colouring matter with sand and lime. There are also cement-sand bricks, cement-lime-sand bricks, concrete bricks, slag bricks, glass bricks and wood bricks.

2.17.2 (b) *Basic Bricks* :

(i) ***Magnesite bricks*** : The main constituent of this brick is magnesium oxide. About 12 per cent of other oxides are mixed with it and carbon dioxide is driven out by first burning this combination to 800°C. Bulk of magnesia thus burnt is sinistered at 1800°C and mixed with 1 to 5 per cent of calcined magnesia. Small quantity of tar or magnesium chloride is some time added to improve plasticity. The bricks are then moulded, dried and burnt. These basic bricks are widely used as lining for basic refractory furnaces such as blast furnaces, copper furnaces, open hearth furnaces and basic Bessemer converter.

(ii) *Dolomite bricks* : Other materials used for preparing basic bricks are calcined dolomite, magnesium carbonate and lime. The powdered material is ground, mixed with water, moulded and burnt like magnesia bricks. Such bricks are called Dolomite bricks. They are not as suitable as magnesia bricks at high temperature as at that temperature, they undergo greater contraction.

(iii) *Bauxite Bricks* : Bauxite containing 50% alumina and iron oxide is heated and powdered 15 to 30 per cent of fire clay in powdered, slate is then mixed and the combination is moulded into bricks and burnt. On account of very high shrinkage at elevated temperature, these bricks are rarely used.

2.17.3 *Neutral Bricks* : Chrome, chrome-magnesite, and carborandum bricks are neutral bricks. These are more inert to slags than basic bricks, and possess resistance to corrosive action of slags and gases.

## 2.18. Strength of Refractory bricks

Refractory bricks have compressive strength from 1500 to 2000 kg/cm$^2$ and water absorption from 4 to 10 percent. They have specific gravity of 24. These bricks are laid in fire clay mortar and lime or cement is not used.

## 2.19 Colour of bricks

The natural colour of bricks depends upon (a) natural colour of clay used, (b) kind of sand used for moulding bricks, (c) state of dryness of bricks before burning, (d) temperature at which bricks are burnt and (e) amount of air admitted to the kiln during burning.

Pure clay free from iron will burn *white* but white bricks are made by adding chalk to clay. Presence of iron in clay will give bricks a tint of *light yellow*, *orange* or *red.* A large proportion of oxide of iron in clay produces *bright red* bricks by burning into red oxide but at high temperatures these are *dark blue* or *purple.* Manganese with large proportion or iron gives *black* colour. Magnesia with iron makes the brick *yellow.* A little lime and iron mixed together give *cream colour*—colour changes to *red* with the increase of iron but *brown* with the increase of lime. Clay containing alkalies, when burnt to high temperature, imparts *bluish green colour.*

### Surkhi

*Surkhi* is the name given to finely powdered bricks. It is also called *artificial puzzolan* as natural puzzolan is burnt silica and alumina. It is more advantageously manufactured in the immediate neighbourhood of brick kilns by grinding in a mill or pounding with rammers when required in large quantities or pounding by hand or a tilt hammer worked by feet when required in small quantity as freshly clay is easier to crush and brick bats are found in abundance near brick kiln. It must be perfectly clean and free from any admixture of foreign substances. Good surkhi should pass through a sieve of *152 meshes to the an* and they are generally made from slightly underburnt or pila bricks. Surkhi required for hydraulic mortar should be ground to impalpable powder. Surkhi once made requires practically no further care, *Limed surkhi* is made from bricks prepared from clay to which 10 to 15% of quicklime is mixed previous to burning. It is extensively used for making mortar.

## II TILES

### 2.20 Tiles (Fig. 39)

Used in engineering constructions are divided into two classes :—

(1) *Common tiles*, used for roofing, flooring, paving, drain, etc.

(2) *Encaustic tiles*, used for decorative purposes in floors, walls, etc.

Tiles are made more or less in the same manner as bricks but they are made thinner for the sake of lightness and larger so that there may be a few joints only. So they have a greater tendency to crack and warp in drying and burning than bricks. Greater care is, therefore, necessary in the tile manufacture than in brick making. Roofing tiles are of several different kinds, but (1) *flat tiles*, (2) *pot tiles* and (3) *pan tiles* are generally used. They are glazed to prevent the absorption of water. They may be plain, curved or corrugated. Projections and grooves of many patent roofing tiles act as ornaments and help in holding tiles firmly on battens or interlocking tiles with each other. *Hip*, *valley* and *ridge* tiles are also made.

### 2.20.1 Manufacture of flat tiles

**Preparation of clay**—The best blue clay for tiles is generally found a few feet below brick-earth. The clay is ground into powder in *crushing roller* (Fig. 2.1) or mills and then thoroughly pugged but for the manufacture of superior tiles, the powdered clay is mixed with a large quantity of water in *tanks* (Fig. 2.17) well stirred up and then the mixture is allowed to settle. The heavier and coarse particles sink to the bottom of the tank and the finer particles are run off into the lower tank, where the water is allowed to dry leaving the fine clay ready for mixing. This method is known as *blunging process*. Sometimes for very fine work, a mixture of ground glass and potteryware is added to clay which makes the tiles hard and impervious to water so that they stand weather better.

2.20.2 *Moulding*. Clay is moulded on pattern of the exact form of the tiles to be manufactured. Well seasoned wood is used for the mould. The moulder sits on the ground under shade with his mould, water bowl and strike in front, clay on his right hand and wood ashes near him. He first sprinkles ashes over his mould, takes with both hands a lump of clay more than sufficient to fill the mould and throws it into the mould after shaping it roughly taking care to fill the corners. The superfluous stuff is cut off by applying the string of the *bow* (Fig. 2.18) across the surface of the mould and he presses the strike, a flat piece of wood 5 cm × 1 cm × 30 cm long, backwards and forwards over the mould to make the surface of clay smooth and level with the top of mould. The moulder lifts the kutcha tile from the mould by slightly pressing his left hand with fingers extended on to the clay in the mould which adheres to the palm and fingers, and places it gently on a burnt flat tile near him. Each succeeding tile is placed flat on the top of the previous one as they are taken out from the mould until a heap of about 15 is collected, when a second heap is started and so on. All terra cotta works and ornamented bricks are moulded in *plaster of Paris moulds* (Fig. 2.19) as the prepared clay for terra cotta is hard and stiff and will not come out of an ordinary mould.

2.20.3 *Shaping and drying*. Two days after moulding, tiles are slightly beaten with a flat wooden mallet to correct the irregularity in shape due to warping. On the next day they are lifted up when

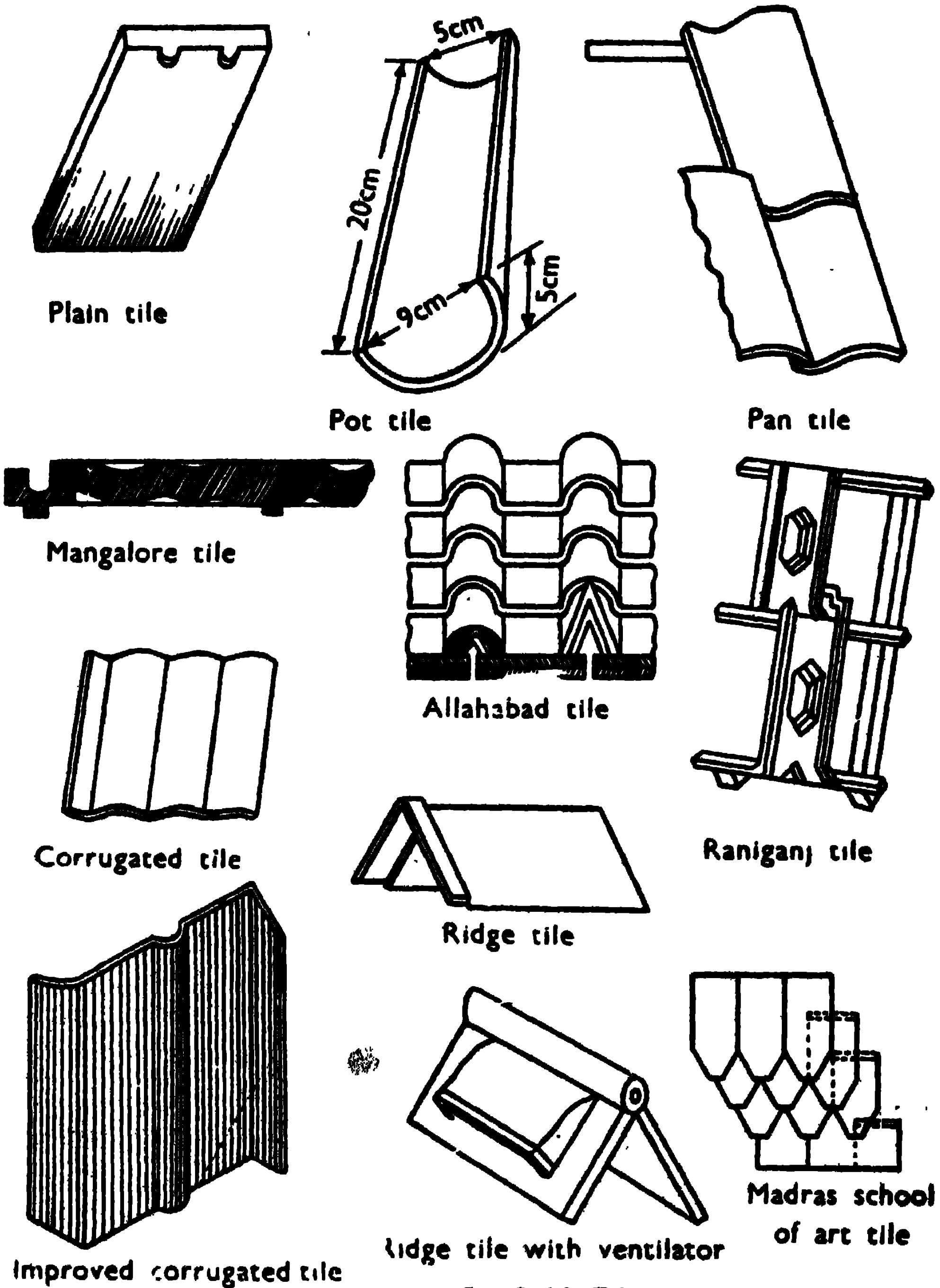


Fig. 2.16 Tiles

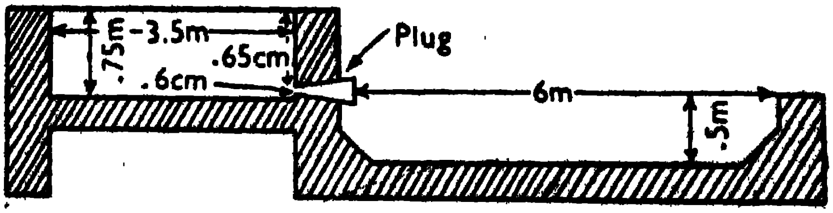


Fig 2.17 Tank

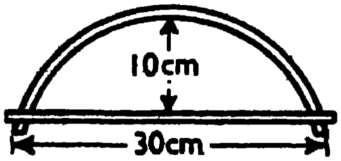
hand-hard and the edges and under surfaces are scraped. They are then placed on edge and left to dry for about 2 days under shade to prevent warping and cracking when they are ready for loading in kiln.

2.20.4 *Burning.* Kutcha tiles on edge are stacked on the brick floor of the *circular kiln* (Fig. 2.20), course upon course and also closely packed. When kiln is full the door-ways are closed with bricks and the top is covered with a course of loose old tiles. The burning is affected with wood. In this case regulation of fire is very important. The fire is gentle at first to drive off moisture and then gradually raised to red heat. Fire is slackened for about 5 hours and then it is raised to white heat which is maintained for about 3 hours and this is repeated for the 2nd time. Now flues are quite filled up with fuel, their mouths are closed with bricks in mud and fire is allowed to burn out gradually to prevent warping. It takes about 3 days' burning day and night. In windy weather the kiln should be sheltered on the weather side otherwise sometimes on that side tiles will be under-burnt and generally they are put on the top of the next kiln for complete burning.

2. *Pot tiles* are made on potter's wheel and burnt with flat tiles in an open clamp. They are laid alternately concave and convex sides uppermost. They are less liable to displacement on roof by birds.

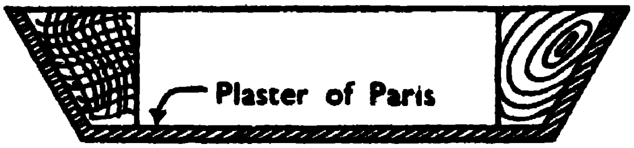
3. *Pan tiles* are shorter, less curved but heavier than pot tiles. They are moulded flat first and then bent to the required form over another mould. Tiles moulded in the case of flat tiles may be shaped into curved forms by bending them one by one on the convex back of a *horse* (Fig. 2.21) which is well sprinkled with wood ashes and then smoothed the back of tiles with wet hands. The bent tiles are placed gently on the ground under shade and when stiff enough to be handled these are taken up and rehorsed. Then edges of tiles are trimmed with a knife and inner faced cleared of ashes, resmoothed with wet hands and placed on their narrow edges till they are hand-hard. Then they are placed on their edges one over the other against a wall till they are ready for burning.

4. *Mangalore tiles* are so called as they were first made at Mangalore but subsequently they have been manufactured at Malabar and elsewhere. Burnt tiles are assorted into 1st, 2nd and 3rd class according to their qualities. Various types of tiles are made. *Glass tiles* are also manufactured for skylights.



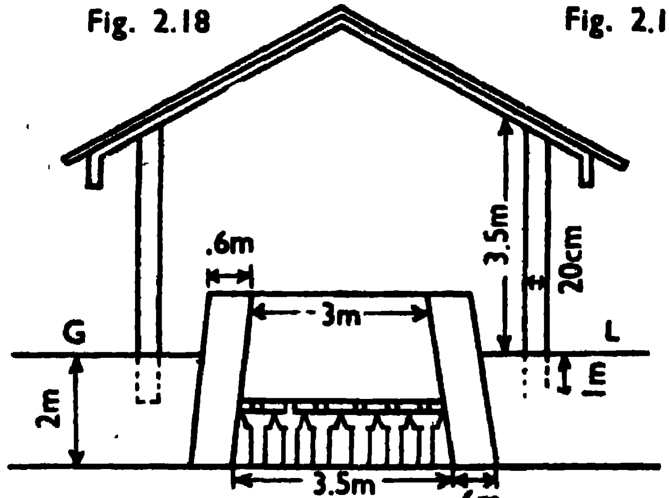
Bow

Fig. 2.18

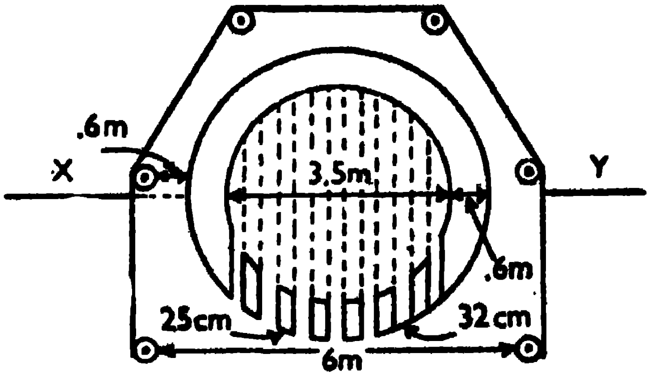


Plaster of Paris mould

Fig. 2.19

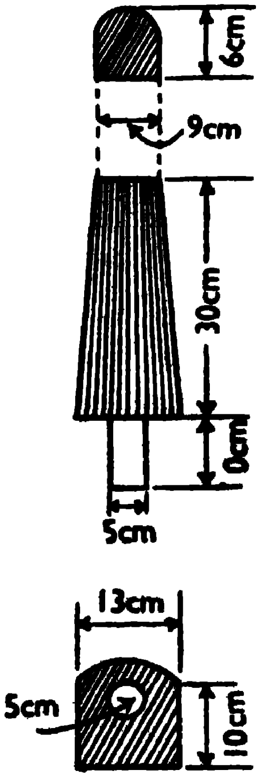


Section on X Y



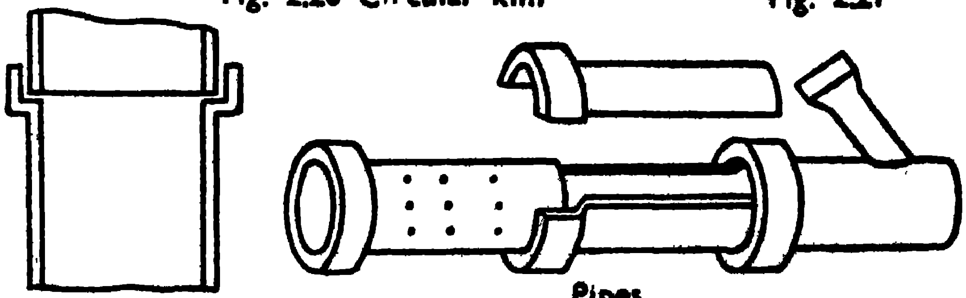
Plan

Fig. 2.20 Circular kiln



Horse

Fig. 2.21



Socket pipe

Fig. 2.22

Pipes

**2.20.5** These tiles are now machine pressed and are very strong and durable. I.S.I. (I.S. 654-1962) lays down the following standards :

(a) *Dimension* :

| Type | Effective length | Effective width |
|---|---|---|
| I. | 317·5 ± 6·4 mm | 209·5 ± 3·2 mm |
| II | 342·9 ± 6·4 mm | 215·9 ± 3·2 mm |
| III. | 249·3 ± 6·4 mm | 222·3 + 3·2 mm |

These dimensions may be rounded as under :

| | | |
|---|---|---|
| I. | 320 mm | 210 mm |
| II. | 340 mm | 215 mm |
| III. | 350 mm | 220 mm |

(b) *Weight* :

The average weight of six tiles when dried to constant weight at 105—110°C shall not be less than 2 kg and not more than 3 kg.

(c) *Absorption* :

On being dried to constant weight at 105—110°C and then immersed in clean water, removed and wiped, the increase in weight (absorption) shall be below 19% for class AA type and below 24% for class A type.

(d) *Breaking load* :

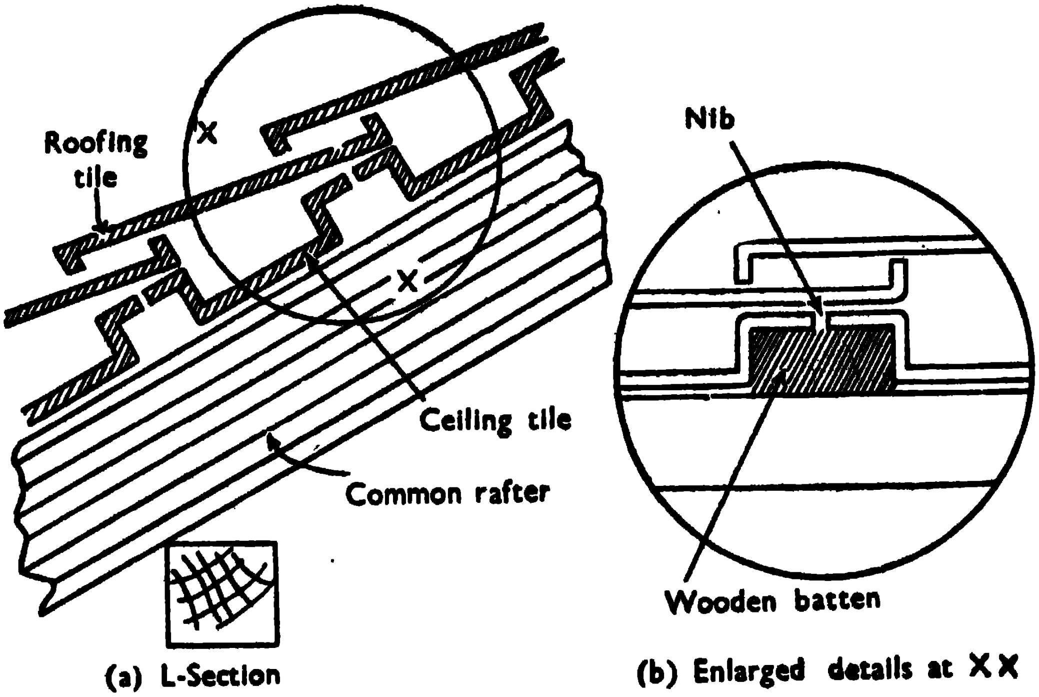
The apparatus shall consist of two parallel self aligning cylindrical steel bearers, with the bearing surface rounded to 40 mm diameter so placed that the distance between the centre could be altered.

Loading device may consist of a bucket and loaded at a uniform rate of 4·5 to 5·8 kg. per minute by allowing lead shots to flow into the bucket.

Three tiles are tested after soaking them for 24 hours at 27°C and 3 in dry condition. The individual breaking load shall be recorded and average taken.

5. *Raniganj and Allahabad tiles*—Excellent tiles of various forms and designs are made at Raniganj and Allahabad potteries.

6. *Corrugated tiles*—These are like pan tiles with 3 or 4 corrugations. They are handsome but not wind-tight.



(a) L-Section (b) Enlarged details at XX

Fig. 2.23 Mangalore Tile

7. *Flooring and paving tiles* are generally made in square, rectngular, hexagonal or octagonal shapes and in sizes varying from 5 cm × 15 cm × 6 mm to 60 cm × 30 cm × 5 cm.

*Encaustic tiles* are those in which colours are produced by mixing colouring substances with the clay but not painted on after the tiles are made. These are generally made from carefully prepared clays and marls mixed with finer clays and colouring substances. These are ornamented by inlaid patterns of different colours. Each tile consists of three layers—the *face* is a coat of pure clay mixed with colouring substances and about 6 mm thick, the *body* is of coarser clay, and the *back* is a thin coat of clay different from that of the body to prevent warping. A plaster of Paris mould is required for the purpose. Upon the mould the form of the inlaid raised pattern is left in relief which will leave hollows in the tile face and then body and the back layers are put. On the back of the tile company's name is marked and some holes are also made for good bonding with mortar while fixed. They are generally made in three varieties : (a) in which pattern is in relief and of same colour as body, (b) in which pattern is indented and coloured, and (c) in which pattern is formed by filling indentations with clay of different colours. The green tiles are then trimmed, dried, and baked in domed kilns. They may be glazed if required by dipping them in a mixture of powdered glass and water and reheated. They are used for paving or wall decoration but the raised ones are used for walls only.

9. *Porcelain or glazed tiles* are made by *dry or wet* process. In dry process prepared clay is ground and pressed into shape. Tiles made by the process stand firing better but do not stand weather well. In wet process prepared clay is pressed into shape while moist, dried and then burnt.

10. *Mosaic paving slabs* are prepared by arranging tesserae in the required pattern. Rough frame is prepared by strips of wood. Portland cement is then put over the backs of the tesserae and the whole strengthened forming a slab by two layers of ordinary tiles set in cement.

11. *Majolica tiles* have raised patterns and are opaque glazed. They are not very durable and so used for walls.

12. *Drain tiles* are circular or segimental tiles used for the construction of drains. Drain tiles are rarely used now-a-days. These are replaced by concrete, stoneworks or unglazed earthenware pipes.

13. *Sanitary tiles* of size 15 cm × 15 cm × 1 cm are wall and floor tiles. These are made with dry mixture of fire clay and crushed stone. They are burnt at high temperature and the face is then dipped in glazing solution and again fired after drying, giving bright smooth surface.

**2.20.6** *Colouring bricks and tiles. Natural colour* is due to ingredients present in clay used for the manufacture of bricks and tiles. They may be coloured artificially as well. Artificial colouring in bricks and tiles may be done either (1) by mixing some colouring substance with the clay which will give the required colour when burnt, or (2) by dipping the burnt bricks or tiles while hot in a colouring liquid. The 1st method is adopted for cheap colour in abundance while 2nd method is adopted for expensive colours and also to built-up walls.

In the 1st method colours are mixed with clay in different proportions according to the required tint—iron burns red at low temperature but black at high temperature, red ochre burns yellow, manganese burns black, etc. In the 2nd method the colouring matter is added to a mixture of linseed oil and turpentine containing a little litharge as a drier. The usual colouring matters are Indian red for dark red bricks, manganese for black bricks, French ultramarine for blue bricks, and white lead and manganese for grey bricks. Boiling coal-tar may be used for black colour.

The bricks or tiles to be coloured are heated on an iron plate and dipped when hot in the colouring solution, one at a time, and placed on a table to dry. When dry they are slightly washed with cold water and allowed to dry. If it is burnt again it will be covered with a glaze. The colouring liquid may be applied hot with a brush on a thoroughly cleaned wall already built up.

### 2.21 Structural Hollow Clay Tiles

Various types of hollow tiles used for foundation walls, floors, partition and other structural works are known as structural tiles. As they are specially prepared, they are fire proof, rat proof, termite proof and light weight. On account of the above property they are economical in construction and maintenance.

Load bearing tiles may be extra load bearing or ordinary load bearing. Compressive strength of load bearing walls is about 80 kg/cm$^2$ on end and 50 kg/cm$^2$ laid flat. These values may be reduced for non load bearing walls.

The four walls of the tile all round the hollow interior are known as shell and the intermediate partition is known as web. The thicknesses of the shell and the wall in the case of construction tile should be more than 2 cm and 1·25 cm respectively. The width of the tile in any construction, measured along the direction of the wall thickness should be less than 4.5 times the average thickness of the upper or lower load bearing shell. There should be no cracks, blisters, laminations or roughness in the tiles suitable grooves to form key for the plaster of not more than 2·5 cm width and depth varying from 1 mm to 5 mm in such a way that the total area covered by the grooves does not exceed half the area of the face should be formed if the tiles are to be plastered. Depending upon the requirement, grooves may be provided in one or both the faces. Grooves need not be provided where no plastering is deserved such as in partition walls.

### 2.22 Efflorescence in Brickwork and remedial measures

The moisture is responsible for bringing soluble salts in any constituent of the masonry such as brickwork facing or mortar and as a result of crystallisation of these salts white spots occur on the surface, when the brickwork is wetted or washed, these spots are washed off.

Calcium, magnesium sulphates, and sodium calcium carbonate, present in the walling material form solution with the water. This seeps to the inside of brickwork and subsequently comes on to the surface. In course of time crystalline deposits are formed on the surface or interior of brickwork due to evaporation of water. As a result of this, the surface gets disfigured and the interior brickwork gets disrupted.

The following steps are suggested to avoid efflorescence in brickwork—

(i) Selection of proper material for the manufacture of the tiles.

(ii) Prevention of moisture either by water proof coping, water repellent mortar, or by the provision of drip courses. In addition to these, the masonry should be protected from rain water; cracks should be repaired and adequate and effective damp proof courses should be provided.

The phenomenon of efflorescence can be eliminated if 2% by weight or cement or lime a water repellent material such as calcium or ammonium siearate is used.

## III. EARTHENWARE AND STONEWARE

**2.23** Earthenware is made by burning at a low temperature and cooling slowly earth or clays mixed with sand, crushed pottery, etc. to prevent shrinkage and is usually soft and porous to some extent. Stoneware is made from refractory clays mixed with crushed pottery and stone, burnt at a high temperature and cooled slowly. The materials, when moulded to required shapes and dried, are burnt in kiln raising heat gradually to high temperature, maintaining the same for 2 or 3 days and allowing to cool slowly. Stoneware is more compact than earthenware. The harder stoneware is of light straw colour, but softer earthenware is dark brown.

Earthenware and stoneware, when glazed, are impervious to water, uneffected by weather or corroding substances. These are largely, used for irrigation drain, sanitary fittings, sewer pipes (Fig. 2.22), damp proof course, acid jars and for making hard refractory paving tiles. They can be tested by tapping. They will emit a dull sound if underburnt or cracked but will ring true if well burnt and sound.

Clay possessing a high degree of tenacity and plasticity is used in the manufacture of various kinds of earthenware and when of sufficient purity it is of use in the manufacture of glazed pottery and high class porcelain. Porcelain being of white colour is sometimes called *whiteware*.

**2.23.1** *Glazing—Object*—Surfaces of bricks, tiles, earthenware or stoneware are sometimes glazed to improve their appearance and also to protect them from the action of weather, sewage, chemicals, or other destroying agents.

Glazing may be *transparent* like glass or *opaque* like enamels.

2.23.2 *Transparent glazing*—It may be divided into two classes : 1. *Salt glazing* and 2. *Lead glazing*. *Salt glazing* is effected by throwing common salt into the kiln, containing the articles to be glazed at the close of the burning operation. The vapour of the salt sticks to the exposed surfaces of the articles coating them with a thin film of transparent glass. It is used for articles made from fireclay and stoneware. *Lead glazing* is effected by dipping the hot article to be glazed in a bath containing oxide of lead and tin when particles of these materials adhere to the article dipped. The article is then withdrawn and reburnt when high temperature of the furnace melts it forming a film of glass over the exposed surface. It is used for terra cotta.

Salt glazing is cheaper but lead glazing is used far wares made from inferior clays which cannot stand the high temperature required for salt glazing.

2.23.3 *Opaque glazing*. The articles to be glazed is dipped before burning into a slip formed of superior clay, finely worked, dried and then placed it in a potter's oven till the composition runs and brought to the required colour. It is used where it is desired to give the whole or any part of the article a better appearance than that presented by the burnt material. Cups, dishes, basins, etc. are opaque glazed.

## 2.24 Terra cotta and other claywares

*Terra cotta* is a kind of earthenware. A large amount of ground glass, pottery and sand is added to a mixture of various clays. This is then ground to fine powder, put into a large water tub and thoroughly mixed with spades. Water is then run off from the tub. This clay is thoroughly pugged when dry enough to make it fit for the moulder. A quantity of colouring substance is added according to the shade of colour required. It is usually moulded into hollow blocks. The blocks should be shaped so as to form a good bond with the brickwork or other materials used for the backing and carefully dried and burnt into special kilns without contact with fire. This is hard, impervious to water and will stand weather better than most kinds of stone. It is used as a substitute for stone in ornamental parts of buildings, such as, cornices, capitals and bases of pillars, etc. It is not used much in

India. Terra cotta is burnt at a lower temperature than stoneware. It is as strong as stone and so tough that it is used for paving as well.

Porous terra cotta is made by mixing saw dust in the clay, which burns in kiln and leaves pores inside. It is fire-proof and can be sawn and hold nails and screws and also strikes well to plaster.

*Faience* is similar to terra cotta but it is twice fired in kiln. It has a greater colour range and is used on a smaller scale.

Earthenware, stoneware, porcelain and terra cotta are the different types of *ceramic products* i.e. pottery products.

2.24.1 *Merits and demerits.* Terra cottas are more durable, lighter, stronger, harder and cheaper than most building stones. It is also non-affected by atmospheric action and acids, easily moulded into intricate designs and easy to clean. It is fire-proof and most suited for use with R. C. C. as concrete runs into the cavities to form a monolithic whole. But they are slightly twisted due to unequal shrinkage in drying and burning and it has a bad effect in a long line cornice or string course. Moreover, it cannot be fixed during the progress of the work but is done afterwards whereas stone can be fixed at once.

*Claywares* are innumerable, such as, perforated air bricks, damp proof courses, bonding bricks, chimney flue pipes, chimney top, lavatory basin, water closet and urinal, soil pipe, etc.

*Pipes and other claywares* are divided into five classes :—

(1) unglazed earthenware—porous. (2) fireclay-ware—porous when unglazed, inferior to terra cotta or stoneware, used for common articles. (3) Stoneware—strength, durability, resistance to corrosive fluids and its cleanliness have rendered it a reliable material for sanitary works; such as, drainage, sewerage and irrigation purposes, siphon and gully traps, rain and soil pipes, sluice valves, air bricks, closet pans, ornamental works exposed to the atmospheric action and for vessels to hold chemicals. (4) Terra cotta—inferior to stoneware, most absorbent and less close grained, frequently used for pipes and other useful wares. They are manufactured in India at Kaniganj Jabbalpur, Mangalore, Calicut and Ferok. Architectural terra cotta is most suitable for decorated panels, fire place and mentals, tomb stones, door and window frames, arches, string courses, brackets, fountains, chimneys, etc. (5) Portland cement.

## 2.25 Porcelain

It is a ceramic of high grade having good translucency and white in colour. Its absorption is very low as is non porous and it has vitrified structure. It has hard and soft varieties. The composition of hard variety is china clay or kaolin along with quartz and felspar as filter and flux respectively. On account of its hardness and non-absorption it is very suitable for bathroom fixtures and electrical installations. The glazing material is applied before firing which is done only once.

The constituents of the soft variety are white clay mixed with certain percentage of melted glass. The first firing is done upto 1200°C and this once fired material is coated with glazing material and then the temperature of the kiln is raised to 1500°C. Crockery like plates, dishes, tea pots etc. come under this category.

## APPENDIX A

### 2.26 Testing of bricks, tiles etc.

(a) *Sampling* :

50 pieces shall be taken from a lot of 50,000 or part thereof. The sampling shall be done at random during loading or unloading of the bricks or from different parts of the stack.

(b) *Dimensions* :

Twenty pieces shall be selected at random from the sample of 50 pieces mentioned in (a) above. All irregularities of the bricks, namely projections or particles of clay are removed and bricks arranged in a straight line. In the same way burnt bricks are laid flat or on edge to determine width and height of the pieces respectively.

The cumulative dimensions of the burnt pieces measured as above shall be within tne limits given below :

| | |
|---|---|
| Length | 367 cm to 393 cm |
| Width and height | 174 cm to 186 cm |

(c) *Absorption test* :

(i) Field test : The test piece shall be weighed dry and after immersion in clean water for 24 hours.

The absorption is given by $\frac{100 \times (\omega_2 - \omega_1)}{\omega_1}$ per cent

where $\omega_1$ = dry weight of the test piece

$\omega_2$ = weight of the test piece after immersion in water for 24 hours and wiping with a damp cloth.

(ii) Laboratory test : Five test pieces of bricks or tiles shall be selected at random and dried to constant weight at 150°C. If the specimen is fairly dry, the constant weight stage may be reached in 48 hours.

The specimen shall then be gradually allowed to cool down to room temperature and the immersed in clean water at 15·5°C to 30°C for 24 hours. The brick or tile shall then be wiped off with a damp cloth and reweighted. Absorption is given by

$$\frac{\omega_2 - \omega_1}{\omega_1} \times 100\%$$

where $\omega_1$ and $\omega_2$ are the weights of the specimen in the dry and wet state respectively.

## EXERCISE II

### A. M. I. E. (I) Examination Questions

1. What are storeware products and how are they manufactured and used ? (May, 1962)

2. What are the requisite properties of earth that is to be used for the manufacture of tiles and firebricks ? (May 1962)

3. Describe fireclay and its properties and uses in engineering industries. (May, 1961)

4. What are the ingredients of earth that are used for the manufacture of tiles ? Explain how the earth is prepared and tiles manufactured on a large scale. (Nov. 1960)

5. (a) Give the characteristics of clay for the manufacture of good bricks. (b) Compare the properties of bricks obtained from clamp and kiln burning. (c) Draw a neat sketch of any continuous kiln and briefly explain its working. (Nov. 1959)

6. Explain briefly the terms : (a) Country bricks, (b) Table-moulded bricks, (c) wire-cut bricks. Describe briefly the process of their manufacture, mentioning their relative merits. (May, 1959)

7. What are the chief points to be observed in selecting bricks for walling ? (May, 1959)

8. Describe one type of continuous Kiln used for burning bricks. How are salt-glazed stoneware pipes manufactured ? (Nov. 1958)

9. Write a brief note on the composition of clays used for (i) common bricks, (ii) roofing tiles, (iii) fire-bricks. Describe the process of manufacturing any one type of ceramic products. (May, 1957)

10. Describe briefly the various operations involved in the manufacture of bricks, pointing out the importance and necessity of each. Draw a neat sketch of a brick kiln. Explain the technique of glazing whiteware products. (Nov. 1956)

11. (a) What are the comparative advantages and disadvantages of kiln and clamp burning of bricks ?

(b) Enumerate the different kinds of bricks generally turned out by, and received from manufactures, and their uses for construction purposes.

(c) Describe the composition and method of manufacture of any two of the following : Terra-cotta, Fire bricks, Stoneware pipes. (May 1956, Nov. 1950)

12. What are the common defects in brick and how are they detrimental to its use ? Compare the relative value of bricks as a material of construction with that of stone and concrete. (Nov. 1955)

13. Give the qualities of first-class building bricks and indicate how they are influenced by (a) the nature and manufacturing of the clay used, (b) the process of manufacture, (c) the manner of firing. What are the causes of efflorescence in bricks and how can they be avoided ? (Nov. 1954)

14. (a) What are the characteristics of good brick earth ?

(b) Describe in brief the method you would use for burning one lac of bricks in a remote countryside.

(c) How much coal is required for burning a lac of bricks in a Bull's kiln and what is the percentage outturn of first class bricks. (May, 1954)

15. Describe fully with sketches the process of manufacture of common clay bricks as largely practised in India. Indicate clearly the stages and circumstances in which defects may arise, resulting out in outturn of bad bricks. (Nov. 1953)

16. (a) Compare the merits and demerits of burning bricks in clamp and kilns, (b) Give briefly the characteristics of good bricks.

(c) Discuss the relative advantages and disadvantages of bricks as compared with stone as a building material. (Nov. 1953)

17. Enumerate the chief characteristics of clay, as a material used for the manufacture building materials. Describe its behaviour under varying climatic conditions and give some of the chief uses to which it can be put in engineering practice. What sort of clay is suitable for manufacture of roofing tiles ? What difference is there between this clay and the clay suited for the manufacture of building bricks ? (Nov. 1952)

18. (a) What is sand moulding ? What are the advantages of hollow concrete blocks ?

(b) What is the principle of continuous brick kiln ? Show by a line diagram how it is followed in a Hoffman's kiln. (May, 1952)

19. What are the characteristics of good building bricks ? What is their usual size ? How many bricks will be required for 100 c. ft. of brickway, second class, in lime mortar ? What crushing load would such masonry stand ? (May, 1951)

20. (a) What are the tests usually carried out on bricks required for a large construction ?

(b) What are the essential constituents of good brick earth ? How is the quality of brick affected by the excess of one or other of the constituents ?

(c) Describe how fire bricks are manufactured. (Apr. 1950)

21. Write a short note on the harmful ingredients in a good brick earth, stating their effect on the property of the brick. (Nov. 1962)

22. Describe briefly the method of manufacture of bricks, using continuous kiln with suitable sketches. (May 1963)

23. Write a short note on the constitution of brick earth and their property, mentioning also their different classification. Describe with sketches the different stages of brick manufacture. How does the manufacture of brick different for that of the tiles. (Nov. 1964)

24. Describe with suitable sketches the manufacture of Mangalore bricks using continuous kiln. (Nov. 1965)

25. (a) What are the characteristics of a I class brick ? How will you test the quality of brick ?

(b) Write a short note on the harmful ingredients in brick earth stating their effect on brick. (May, 1966)

26. Describe with sketches the manufacture of brick by Bull's brick kiln. (Nov. 1966)

27. (a) What are the different types of tiles ? Mention their various uses in building construction.

(b) Describe briefly the manufacture of Mangalore pattern tiles. In what cases are they used and why ? (Nov. 1963)

28. State the components of earthenware and stone ware products. What are their chief uses ? (May 1966)

## Engineering Services (I) Examination Questions—

29. Give the characteristics of the different kinds of brick generally turned out from brick kilns, and their uses for construction purposes. (1962)

30. What is the most convenient size for burnt bricks ? Give your reasons. What relation should the breadth of a brick bears with length and why ?

A certain construction work requires large and continuous supply of bricks. Explain the type of kiln you would adopt for obtaining such supply. What are its advantages ? (1960)

31. What ought to be the quality of an earth for making good bricks and why ? Why is sand added to brick-earth ? What would finally happen if bricks were made from earth containing salts and kankar respectively ?

32. What are the different classes of brick-earth ? Give the composition of a good brick-earth. If you are called upon to manufacture bricks in a particular locality, show how you would proceed to satisfy yourself of the suitability of the earth. What is the rule that governs the size of a brick i.e. the proportion of length and breadth of a brick to ensure good bonding ?

33. What is good brick earth ? Presence of what material in excess in the clay makes the brick brittle, and what is pure clay ?

34. If you were moulding bricks in a field the clay of which in places were more sandy than in others, would you take any precaution to see that all the bricks when burnt measured the same size ? If so what would you do ?

35. What is a pug mill ? What is its use, and advantages ? How is it set up ? Describe the working of it with dimensioned sketches. What other appliances do you find arranged close to a pug mill ?

36. Describe with sketches the process of burning about a lakh of bricks in a clamp. What are the advantages and disadvantages of clamp burning compared with kiln burning ?

37. Describe briefly with sketches the method of burning bricks in a Bull's kiln. What is the difference between—(1) Slop moulding and (2) Sand moulding ? Sketch a standard mould of the box type with dimensions. What is the P. W. D. classification of bricks and for what specific purposes the different kinds are used ?

38. Describe the composition of good brick-earth. On what does the colour of bricks depend ? Explain how you would test a brick. Sketch a section of a brick clamp to burn one lack of bricks, nothing the amount of coal and the number of courses of raw bricks you would put in the respective layers.

39. In classifying the outturn of a brick kiln, what qualities would you look to in distributing it into 1st, 2nd and 3rd classes ? What percentage would you expect to find in each class as the average outturn of a Bull's kiln ?

40. Give dimensioned sketches of sancha and table moulds ; and explain briefly the merits and demerits of each.

41. Define—Marl. loam, malm, fireclay, terra-cotta and encaustic tiles and explain their uses. Describe the process of burning a clamp illustrating it where necessary and state what size of clamp would yield 1 lakh of bricks.

42. What are the tests of I class bricks ? In what parts of buildings you would use I class, II class and III class bricks ? What kind of jhama is unsuitable for khoa or chips ? Why is not jhama suitable for building structure ?

43. What area of ground is required for burning 50 lakhs of bricks in a Bull's kiln yearly for three sessions ? Give a plan of the ground with dimensions showing how it is to be subdivided for different purposes.

44. What materials are necessary for making firebricks, terra-cotta ware, and roof tiles ? Describe any process you know for making one of the three classes of articles named.

45. What are the characteristics of first class bricks, picked jhama, jhama and second class bricks and where are they used for in building ? Briefly describe the methods of burning bricks commonly adopted in your State. What are the relative advantages of each method ?

46. Compare the burning of bricks in Bull's kiln and country clamp and discuss the reason that would lead you to adopt one or the other of the systems in specific cases.

47. What size clamp will burn a lakh of bricks and what time will it take to burn and cool ? How does brick burner know when the burning is finished ?

48. What are encaustic tiles and for what purposes are they used ?

# Chapter 3

## LIME, CEMENT, MORTAR, CONCRETE, ETC.

**3.1** In engineering works, stones, bricks, and sometimes tiles are set in mortar resting on beds of concrete and finished with plaster or pointing with or without white or colour washing. Lime or cement is the binding material in the mixture of mortar, concrete, etc.

### I. LIME

### 3.2 Sources of lime

Lime is not generally found in nature in the free state but it is obtained by burning limestone, a raw material, found in limestone hills or limestone boulders found in the beds of old rivers, or kankar found below ground, or shells of sea animals. *White chalk* is pure limestone and *kankar* is an impure limestone.

### 3.3 Varieties of lime

The three varieties of lime generally used are :

(1) *Stone lime* (almost pure lime),

(2) *Kankar lime* (impure lime), and

(3) *Shell lime* (very pure lime).

Stone lime is used for making mortar with sand for works above ground, for terrace roofs and floors, for plaster and also for white-washing when mixed with shell lime. It is used with surkhi for works below ground as it has got hydraulic property. Kankar lime is used with sand for works below ground and in thick masonry walls where there is no free access of air. It is also used as mortar in superstructure works in places where stone lime is not available. Shell lime is used in lime punning or white-washing as it is very costly. The more commonly used stone limes in Calcutta market are *Sylhet lime*, *Katni lime* and *Sutna lime*.

## 3.4 Explanation of terms

*Limestone* ($CaCO_3$) is carbonate of lime.

*Calcination* is heating to redness in air.

*Lime* or *Cement* ($CaO$) is the product obtained by the calcination of limestones or other calcarious substances, the effect of which is to drive off the carbonic acid and moisture they contain. Chemically lime is oxide of calcium.

| $CaCO_3$ | $=$ | $CaO$ | $+$ | $CO_2$ |
|---|---|---|---|---|
| Limestone<br>or<br>Calcium carbonate | | Calcium oxide<br>or<br>quick lime | | Carbon dioxide<br>(gas) |

*Quick lime* or *Caustic lime* ($CaO$) is the resulting lime as left immediately after calcination of a comparatively pure limestone. It is amorphous, highly caustic, absorbs moisture quickly and has no affinity for carbonic acid. It remains in this state only for a short time unless kept in a dry place.

*Slaking* is the process of chemical combination of quick lime with required quantity of water for killing the heat and getting into powder form for use.

| $CaO$ | $+$ | $H_2O$ | $=$ | $Ca(OH)_2$ |
|---|---|---|---|---|
| Quick lime | | Water | | Hydrate of lime |

*Slaked lime* or *Hydrate of lime* [$Ca(OH)_2$] is the product formed by the absorption of required quantity of water by quick lime. It is the ordinary pure lime that we see in the market. In this state it has power of absorbing carbonic acid from the atmosphere in presence of moisture and forms particles of carbonate of lime, setting free the moisture absorbed. Slaked lime when kept in a damp place is always converted on the surface to carbonate of lime which is useless. That is why lime should be used as fresh as possible.

*Setting* is the hardening of lime or cement, which has been mixed to a paste with water.

*Drying* is quite different from setting. Water in the paste evaporates during drying but no setting action takes place.

*Hydraulicity* is the property due to which lime or cement will set in damp places or under water or in thick masonry walls where there is no free access of air. Hydraulicity is due to the crystallizing energy of the aluminate and the silicate of lime. Pure limestone, such as, white chalk and marble and also a mechanical mixture of limestone and sand have got no hydraulic property.

### 3.5 Constituents of limestone that produce hydraulicity

1. *Clay* is the most important constituent that produces hydraulicity in lime, but such action does not take place if it is in excess. 2. *Soluble silica*—Hydraulicity occurs when both silica and alumina are present in chemical combination with limestone. 3. *Carbonate of magnesia* reduces slaking but increases the setting process. 4. *Alkalies and metallic oxides* tend to become soluble silicates at low temperature only and thus cause hydraulicity. 5. *Sulphate* tends to reduce slaking but increases setting action only when it is not in excess.

### 3.6 Classification of lime

Limes obtained by calcining limestones are divided into following classes according to their action in slaking and setting :

1. *Rich, fat, common, high calcium, air or pure lime.*
2. *Lean, meagre or poor lime.*
3. *Hydraulic or water lime*— $\left\{\begin{array}{l}\text{Slightly hydraulic lime.}\\\text{Moderately hydraulic lime.}\\\text{Eminently hydraulic lime.}\end{array}\right.$
4. *Hydraulic or water cement—natural or artificial.*

### 3.7 Comparison between pure or common lime and hydraulic or water lime

1. Pure lime contains clay from 0 to 5% and hydraulic lime contains clay from 12 to 25%.

2. Pure lime slakes readily but hydraulic lime slakes slowly with difficulty according as clay is less or more.

3. Pure lime makes a good paste with water and dissolves in water frequently changed but hydraulic lime forms a thin paste with water and does not dissolve in water though frequently changed.

4. Mortar of pure lime will never set or harden under water or in moist places, such as, foundation or interior of thick masonry walls where there is no free access of air but mortar of hydraulic lime will set rapidly in all moist places.

Comparison between the different classes of lime

| NAME OF LIME | PERCENTAGE OF IMPURITIES | SLAKING ACTION | SOLUBILITY IN WATER | SETTING ACTION | HYDRAULIC PROPERTY | USE |
|---|---|---|---|---|---|---|
| 1. Rich, fat, common, air, high calcium or pure lime | Impurities, such as, sand and clay not exceeding 5% | Slakes vigorously, volume is 2 to 2½ times that of quick lime. | Makes a good paste with water & dissolves when water is frequently changed. | Sets slowly in air. Lime mortar sets in thin joints but surkhi mortar has hydraulic property and sets in thick walls or in foundations. | Not hydraulic and so not used in thick walls, wet foundation or under water. | Used as mortar and a base for distemper, in white washing and other sanitary purposes. Mostly used in the manufacture of artificial hydraulic limes and cements and in all chemical industries as the cheapest form of alkali. |
| 2. Lean, meagre or poor lime | Greater than 7% | Slakes sluggishly, expands less than fat lime. | Makes a thin paste with water & won't dissolve even if water is changed. | Sets or hardens very poorly. | Not hydraulic. | Makes a poor mortar, used in inferior structure or in places where good lime is not available. |
| 3. Hydraulic or water lime<br>(a) Slightly hydraulic lime<br>(b) Moderately hydraulic lime<br>(c) Eminently hydraulic lime | 5 to 10%<br>11 to 20%<br>21 to 30% | Slakes slowly after a few minutes.<br>Slakes after 1 or 2 hours.<br>Slakes with difficulty. | ,, | Sets in 3 weeks after inmmersion.<br>Sets in a week under water.<br>Sets in a day. | Hydraulic. The larger the proportion of clay the greater is the hydraulic property. | Used in damp places and in places where there is no free access of air |
| 4. Hydraulic or water cement | 31 to 40% | Does not slake, reduced to a paste by grinding. | ,, | Sets in a few minutes either in air or under water. | More hydraulic. | Used in damp places and even under water, mostly used in reinforced concrete. |

3.8 I.S.I. has classified lime in the following three categories :

| | |
|---|---|
| Class A | Eminently hydraulic |
| Class B | Semi-hydraulic |
| Class C | Non-hydraulic or fat lime. |

Eminently hydraulic lime is used for mortars and for lime concrete work and is very useful for under water construction. Its hydraulic property is imparted by the 25 percent alumina (clay) content. It slakes with difficulty and readily sets under water.

Semi hydraulic lime contains about 15 per cent of alumina or clay and sets under water at a slower rate than hydraulic lime and is used for mortars and concrete.

Non-hydraulic or fat lime is produced from pure limestone and slakes vigorously with the addition of water and does not set under it It does not have any strength and is used for white-washing and colour-washing. When mixed with pozzolanic material like surkhi or cinder it acquires hydraulic properties.

### 3.9 Characteristics of good lime

Good lime must (1) be free from fuel ashes and under burnt particles with not more than 5% of other impurities ; such as, silica, alumina, etc., (2) be found chiefly in hard lumps, (3) slake readily in water, and (4) dissolve in soft water frequently changed.

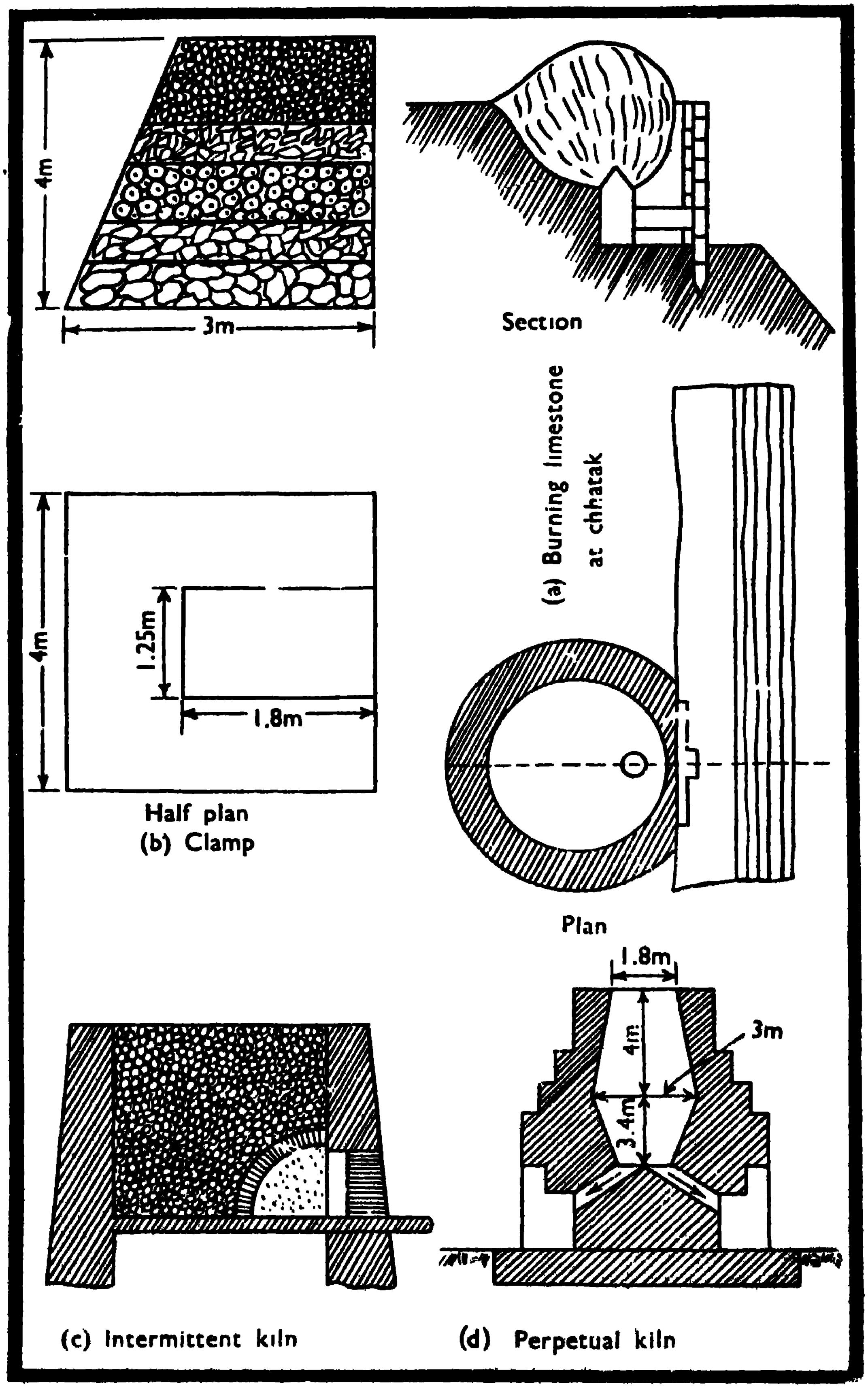
### 3.10 Tests of limestone whether pure or hydraulic

Pure limestone dissolves in weak acid with effervescence while impure or hydraulic limestone dissolves partially in weak acid and there will be little or no effervescence but clayey odour will be emitted. The best test is to burn a sample of the stone and to judge it by the slaking action and also by the hardness of balls made of the lime when kept in a glass full of water.

### 3.11 Burning of limestones

Limestones may be burnt either in clamps or in kilns as in the case of bricks.

*Clamp burning* (Fig. 3.10)—The clamp consists of alternate layers of limestones and fuels, such as, wood, coal or charcoal but not cow-dung cakes laid in a heap about 3·5 m high with sloping sides which are plastered over with mud to retain as much heat as possible. It is fired through fire places at the bottom. If charcoal is used as fuel the limestone is thoroughly mixed with it and made into a heap. Clamp burning



(a) Burning limestone at chhatak

(b) Clamp

(c) Intermittent kiln

(d) Perpetual kiln

Fig. 3.1 Lime kilns

is uneconomical as much heat is lost through mud plaster which cracks by the heat from inside and gives an inferior quality of lime, as lime produced partly slacks by the entry of moist air through cracks in mud plaster and falls into powder and also gets mixed with the fuel ash which cannot be separated. Clamp burning is adopted only when lime is required in a small quantity.

**3.11.1** *Kiln Burning.* Limestones should be burnt in kilns, which are circular enclosing walls to confine heat and so to economise fuel: It will not pay to build a kiln for burning lime in small quantity but should be adopted when a large quantity of lime is required. Kilns may be either (1) ***Flame kilns*** where limestones are in contact with the fuel or (2) ***Flare kilns*** where limestones are separated from fuel but flames only reach stones. The systems of calcination are (a) *continuous, running or perpetual* and (b) *intermittent.*

**3.11.1.1** In *flame kiln* fuel and limestones are loaded in alternate layers and the burning may be either intermittent or continuous. The *intermittent flame kiln* (Fig. 3.1c) is circular in section and has an opening near the base for a flue made by big limestones in an arch form over which fuel and limestones are loaded in alternate layers. Fuel is used for first ignition and kept closed when stones are burnt. It is then allowed to cool and the lime is removed from top. The empty kiln is reloaded and the operation is repeated. There is much waste of time and fuel as each complete operation takes about a week and the kiln is allowed to get cool for each charge. In the *continuous flame kiln* (Fig. 3.1.d) limestone and fuel are introduced from top in alternate layers, burnt lime is generally drawn out from bottom through small arches in the wall made for the purpose, fresh limestone and fuel are added from the top to make up for the burnt lime removed and the process is repeated. Burning goes on continuously day and night until lime is wanted or the kiln needs repair. There is a much saving of time and fuel as the process is continuous and the kiln is not allowed to get cool for fresh charge. This is best suited when a large quantity of lime is continuously required.

**3.11.1.2** *Flare Kiln.* (Fig. 3.1.c) is worked on the intermittent system. In this system coal is kept under the arches and limestones are packed over it so that flame only reaches the stones above coal in the kiln.

Flare kiln yields a better lime as it is not mixed with fuel ash while flame kiln yields an unequally burnt lime but is more economical as it can be readily adopted for continuous burning.

Gradual heating is necessary ; underburnt fat lime or overburnt hydraulic lime becomes dead and will not slake.

*Quantity of coal in limestone burning*—3·7 tonnes of limestones require about ·74 tonne of coal to burn and produce about 3·33 tonnes of quick lime.

3.11.2 *Limestone Burning at Chhatak Sylhet* (Fig. 3.1 a). The site selected for the purpose is the steep bank of a river. The limestones are heated gradually in a short of flare kiln and fuel used is reeds. When the burnt stones cool down they are spread over an even ground near the kiln for air slaking and then water is sprinkled over them until reduced to powder. The process is very simple and inexpensive.

### 3.12 Manufacture of hydraulic of lime

Hydraulic lime may be manufactured either naturally by burning in kiln an impure limestone, such as, kankar not containing more than 30% of clay with coal or charcoal as fuel, or artificially by calcining a mixture of limestone and clay in correct proportions in a kiln. If the limestone used in the manufacture of hydraulic lime is soft, it is ground into powder and mixed with correct proportion of clay and then burnt in kiln, but if the limestone is hard, it is generally burnt and slaked first and then mixed with the correct proportion of clay and reburnt. The burnt product is slaked with water or ground into a fine powder and screened before it is ready for use. A lime that is burnt twice is called *twice kilned lime.*

3.12.1 *Slaking.* There are two ways of slaking lime—(1) by sprinkling water uniformly over the heap of quick lime and then raking the heap thoroughly with phaorah or (2) by dipping quick lime in a basket for required time and throwing it in heaps on level ground.

Fat lime slakes readily and within two or three hours a large quantity may be slaked but hydraulic lime takes 12 to 48 hours in slaking according to the extent of their hydraulic properties.

In case of fat lime all the required water is added at the out-set but in case of hydraulic lime little water is added at first and then add water gradually till it slakes thoroughly.

The quantity of water required for slaking varies with the pureness and freshness of lime and is approximately between one third to one half of its bulk. A pure lime requires more water than hydraulic lime and a fresh burnt lime requires more water than old lime.

**3.12.2** *Grinding.* Pure stone limes slake readily and fall into powder and are then ready for mixing with other ingredients to make mortar. But impure or hydraulic limes often do not slake at all and have to be ground to powder after burning before they are used for mortar. Pulverizing may be done by hand with wooden beaters when quantity is small, but when a large quantity is required a mill worked by bullocks or steam power or a machine is usually employed.

### 3.13 Testing of lime

Hydraulic lime mortar—lime : sand : : 1 : 3.

Adhesive strength (with bricks) after 7 days' curing = 2·25 kg/cm$^2$

Tensile strength (briquette test—1 sq. in.) after 21 days' curing = 6·3 kg/cm$^2$

Compressive strength (5 to 7·5 cm cube test) after 21 days' curing = 35 kg/cm$^2$

### 3.14 I.S.I.

Specifies the following tests for lime and the same are briefly described below :

(i) *Visual inspection* : The lime sample is examined for colour which may be pure white, ordinary white, or dirty. The whiteness is an indication of fat or pure lime. Lump form is an indication of unburnt lime or quick lime.

(ii) *Chemical analysis* : It is done to find the cementation and hydraulic properties of the sample. The limits for various values are given in the following table :—

Cementation value of lime is also calculated from the following formula :

$$\text{Cementation value} = \frac{2{\cdot}8A + 1{\cdot}1B + 0{\cdot}7C}{D + 1{\cdot}4E}$$

where A = Silica oxide ($SiO_2$) content

B = Aluminium oxide ($Al_2O_3$) content

C = Ferric oxide ($Fe_2O_3$) content

D = Calcium oxide (CaO) content

E = Magnesium oxide (MgO) content.

*Chemical Composition : Limits*

| Sl. No. | Constituent | TYPE OF LIME | | | | |
|---|---|---|---|---|---|---|
| | | Class A | Class B | | Class C | |
| | | Per cent | Quick (Per cent) | Hydraulic (Per cent) | Quick (Per cent) | Hydraulic (Per cent) |
| 1 | Calcium & Magnesium oxide<br>(i) Min ... ...<br>(ii) Max ... ... | <br>60<br>70 | <br>70<br>— | <br>70<br>— | <br>85<br>... | <br>85<br>... |
| 2 | Silica, alumina & ferric oxide min. | 2 | 3 | 2 | ... | ... |
| 3 | Insoluble residue in hydrochloric acid less the silica. | 2 | 3 | 2 | ... | ... |
| 4 | Loss of ignited (max) | — | 5 for lump lime<br>7 „ ground lime | —<br>— | 5 for lump lime<br>7 „ ground lime | ... |
| 5 | Carbon dioxide (max) | 5 | 5 | 5 | 5 | 5 |
| 6 | Magnesium oxide (max) | 5 | 5 | 5 | 5 | 5 |
| 7 | Insoluble matter in sodium carbonate solution (max) | 5 | 5 | 5 | 5 | 5 |
| 8 | Residue on I.S. sieve 85 after shaking. | — | — | ... | 10 | 5 |

(iii) *Hydraulic acid test*—The purpose of this test is to assess the classification and carbon content of lime.

Place a tea spoonful of powdered lime in a test tube and note the level of lime. Stir with glass rod and leave the test tube with the contents for 24 hours.

If effervescence is in abundance, it indicates high percentage of calcium carbonate.

The insert residue at the bottom indicates the proportion of inert material.

The formation of a thick jel, which will not flow even when the test tube is turned upside down shows eminently hydraulic lime. If the jel tends to flow on being tilted, it indicates fubly hydraulic lime. Absence of jel indicates non-hydraulic or fat lime.

(iv) *Soundness test*—The test is carried out in "Le Chatelier" apparatus shown in Fig. 3.2.

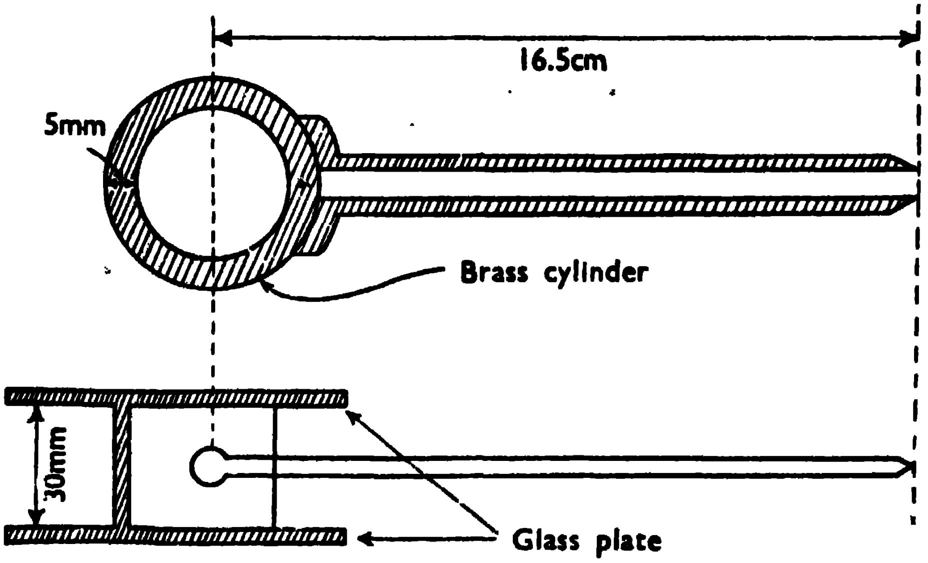


Fig. 3.2

**"Le Chatelier" Apparatus**

The brass cylinder is placed on a glass plate and filled with cement, hydrated lime and sand mortar (1 : 3 : 12) prepared with 12 percent by weight of water. The mould is covered at the top by another plate and left for one hour. The distance between the indicator needles is then measured. The mould is then placed in a damp-air cup board for 48 hours and then subjected to action of saturated steam for 3 hours (without immersing in boiling water). The mould is allowed to cool and the distance between the ends of the two indicators is measured again. The increase in the indicator ends should not be more than 10 mm. (allow 1 mm for expansion of added cement).

I.S. 1624-1960 gives popping and pipping tests for fat lime. Pats are prepared by mixing 70 gm of hydrated lime with 70 ml of water and 10 gm of plaster of Paris. They are subjected to steam action and examined for disintegration, popping and pitting. Any of these occurrences is an indication of unsoundness of lime.

(v) *Test for workability*—Throw a handful of mortar, on the surface where it is to be used. The area covered by the mortar and the amount of mortar picked up gives the indication of the suitability of various ingredients in lime mortar namely lime, sand and water, with or without cement, surkhi etc.

(vi) *Test for transverse strength*—The purpose of this test is to test the strength of lime used in the works.

2·5 cm × 2·5 cm × 10 cm test specimens are prepared and cured for 28 days at 90% humidity at a temperature of 24°C to 30°C. These specimen are immersed in water for half an hour and tested in the apparatus for transverse strength (see Fig 3.3).

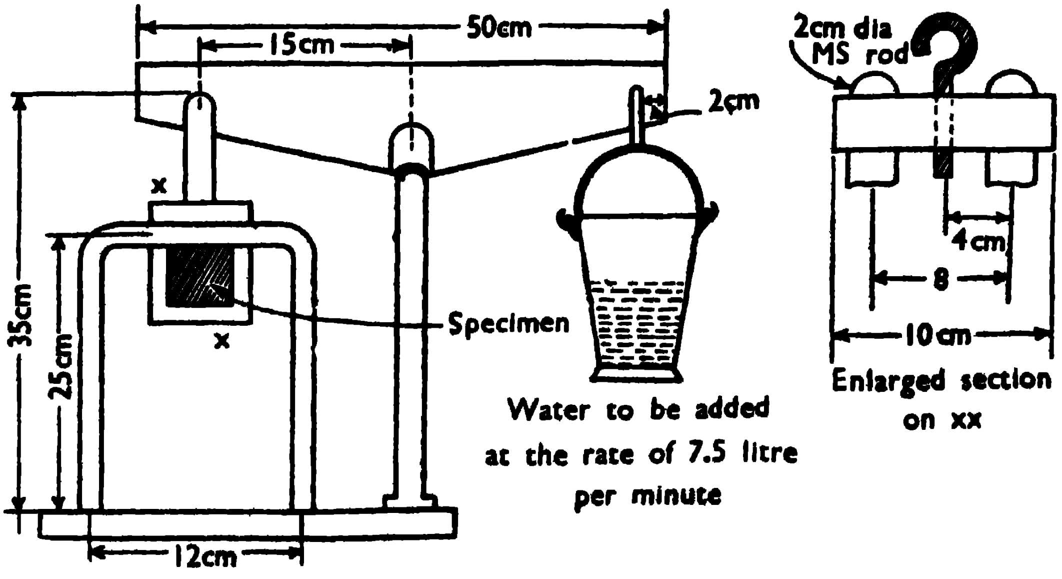


Fig. 3.3 Apparatus for transverse strength test

The specimen rests symmetrically on two parallel rollers 8 cm apart as shown in Fig. 3.3 and load is applied through a third roller of the same size at a point midway between the other two at the rate of 7·5 kg per minute till the specimen is broken.

The modulus of rupture of the test specimen is calculated as follows :

$$m = \frac{3WS}{2\,bd^2}$$

where $m$ = modulus of rupture in kg/cm$^2$

W = breaking load in kg.

S = span = 8 cm

$p$ = breadth of specimen = 2·5 cm

$d$ = depth of specimen = 2·5 cm

Substituting the above values

$$m = \frac{3W \times 8}{2 \times 2{\cdot}5 \times 6{\cdot}25}$$
$$= 0{\cdot}768W.$$

The value of $m$ should be more than 10·5 for A class and more than 7·0 kg/cm$^2$ for B class respectively.

### 3.15 Storing of lime

Limes are slaked or pulverised near the work if possible and used while fresh as slaked lime absorbs carbonic acid. It begins to set on the surface if kept stored for a long time and thus a portion of lime is wasted.

| $Ca(OH)_2$ | + | $CO_2$ | = | $CaCO_3$ | + | $H_2O$ |
|---|---|---|---|---|---|---|
| Hydroxide of lime | | Carbonic acid gas | | Carbonate of lime | | Water |

Lime is generally spread out on a wooden or concrete floor in a large weather-tight room and occasionally turned over, otherwise in presence of moist air slaked lime will absorb carbonic acid and will be converted into lumps of carbonate of lime on the surface and thus a portion of lime will be wasted.

### 3.16 Use of lime

Lime is used (a) as matrix for concrete, (b) in the preparation of mortar for bedding bricks and stones in masonry works, (c) as a cementing material in the plaster for covering walls and in pointing for preserving joints, (d) as white-washing, etc.

(a) *Lime concrete*

Lime concrete is extensively used in building foundations and for filling. It is extremely suitable for situations like external surface drains, tanks and soak pits. The foundation can always be laid in lime concrete where early set is not required and structure is not subjected to heavy stresses. Addition portland cement increases the strength of lime concrete. The strength and durability of lime concrete is considerably increased by the admixture of pozzolanic material like surki.

(b & c) *Lime mortar*

Lime with sand or surkhi in various proportions, with or without cement forms a very useful and cheap mortar for plastering, pointing, brick and masonry work.

(d) *White-washing etc.*

For presenting a uniformly white surface, pure lime is used for white-washing the interior and exterior surfaces. A variety of different colours can be added to the white-wash to give a colour-wash.

Other situations in which lime is used on a large scale are lime flooring, and lime terracing. 2 to 2½ percent lime is added to stabilise the nature of the soil. The addition of lime reduces the water requirement.

Uses of lime other than as a Building material :

(i) *For agricultural purposes* : Certain types of soils can be improved upon by the use of lime. Although slaked lime becomes useless after long storage as a building material, because of recarbonisation it is very useful for soil corrector.

(ii) *As a disinfectant and for sanitary purposes* : Examples are water purification, and as a material for prevention foul smell in filthy places. It is also used for clarifying muddy water and for treating boiler water.

(iii) *Road construction* : For subgrade preparation in National Highways, and Airport Runways, the stabilisation of soil by the admixture of lime has been found very useful and economical.

## II. CEMENT

3.17 *Cement* is a calcarious substance similar in many respects to eminently hydraulic lime or hydraulic cement but possesses hydraulic properties to a far greater extent. It is distinguished from lime by the property that it does not slake but sets readily when a paste is made out of it.

Cement is divided into two classes ·

1. *Natural cement.*
2. *Artificial cement.*

*Natural cement* is manufactured by burning and crushing to powder, stones containing 20 to 40% of clay, the remainder consisting chiefly of carbonate of lime alone or sometimes carbonate of lime mixed with carbonate of magnesia. It is brown in colour and sets quickly or slowly when mixed with water, according as the proportion of clay in stone is more or less and it is of no great ultimate strength. The best variety of natural cement is known as *Roman Cement.* Natural cement is not much in use in India.

The best variety of *Artificial cement* is known as *Portland cement* due to its resemblance in colour to Portland stone. It is a compound consisting chiefly of silicates and aluminates of lime produced by calcination to incipient vitrification of a mechanical mixture of chalk and clay. There are two methods of mixing chalk and clay—(1) *Wet process* and (2) *Dry process.*

3.17.1 *Wet Process.* The manufacture of cement by wet process may be divided into three stages. *In the first stage* 10% of chalk and 30% of clay which contains some sand, oxide of iron magnesia, etc. are crushed, ground, and then mixed uniformly. Generally the ingredients are crushed in a crushing mill and carried by water into large shallow tanks where it is allowed to settle for several weeks. The water is then run off and the sediment or slurry is dug out, sometimes pugged and dried in an oven.

*In the second stage* the dried slurry is burnt for about 48 hours at a continued high temperature in *bottle-shaped intermittent kilns* (Fig. 3.4) with alternate layers of coke and the mixture, 15 and 10 cm deep respectively until it is in a state of incipient vitrification. Due to calcination carbonate of lime is decomposed and the free lime combines with silica, alumina and oxide of iron. The product of calcination is known as *clinker.* Generally the mixture of clay and limestone is calcined in a rotary kiln which is lined with refractory bricks. It is a steel tube of 2·5 to 3 m in diameter and 30 to 75 m in length. It is inclined to the horizontal and rotates at the rate of one or two revolutions per minute. The mixture enters through the higher end of the tube and descends under gravitation while pulverised coal is injected simultaneously through the lower end with great force. The coal ignites, intense heat is produced, and thereby the mixture is calcined and the process is continuous.

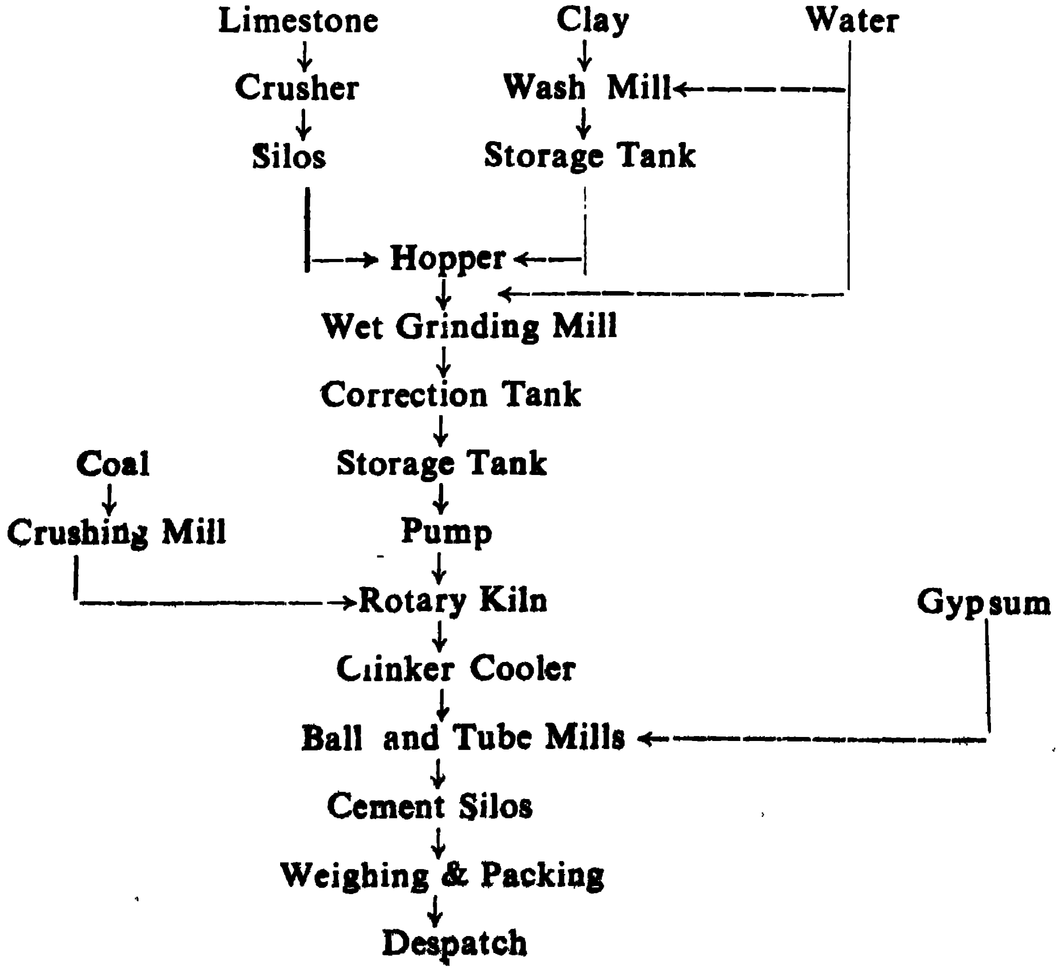
*In the third stage* the clinker is ground to a fine powder, spread on a dry floor for some days for air slaking, and mixed with gypsum about 5% of the cement produced to improve its quality. Gypsum retards on the starting of initial setting after water is added. The sifted cement is packed in barrels or waterproof bags. Cement in a bag weighs ·5 quintal and its volume is ·035 $m^3$. Gypsum ($CaSO_4$, $2H_2O$) is crystalline hydrated sulphate of calcium.

With white chalk, 3 volumes of chalk are mixed with 1 of clay and with grey chalk, 4 volumes of chalk are mixed with 1 of clay.

Portland cement can be manufactured cheaply when underburnt because then a greater bulk of cement is produced with a given quantity of material and moreover it requires less fuel and less grinding. It sets quickly but never has the same ultimate strength as that of properly burnt cement. Underburnt cement is heavy and contains free quick lime and is apt to slake in the work. This defect may be avoided by exposing cement for air slaking. It sets slowly but becomes as hard as stone.

3.17.2 *Dry Process.* Calculated proportions of hard chalk and clay are very finely ground and thoroughly mixed in a dry state. The finely ground mixture is stored in a silos to be fed into rotary kilns. The clinker is then ground to a fine powder, air slaked, mixed with required gypsum and then packed in barrels or bags.

**Flow Diagram for the Cement Manufacture (Wet Process)**



**Chemical analysis of Portland cement**

Chemical test of Portland cement is now recognised. The result of the chemical analysis of a good Portland cement is given below :

| | Per cent |
|---|---|
| Silica ... ... ... | 22·0 |
| Sand and clay (insoluble) ... | 1·1 |
| Alumina and ferric oxide ... | 11·3 |
| Lime ... ... ... | 61·5 |
| Magnesia ... ... | 1·0 |
| Sulphuric anhydride ... | 1·4 |
| Carbonic anhydride and water ... | 0·9 |
| Alkalies .. ... ... | 0·8 |
| | 100·0 |

Lime, silica and oxide of iron give strength. Alumina imparts quicksetting property. Magnesia and sulphur are harmful when in excess. Alkalies cause efflorescence when in excess.

3.17.3 *Properties and Tests of Portland Cement.* A very slight difference in the manufacture of cement may make a great difference in the quality of the material, and so rigid testing is necessary in order to get the proper quality of cement. The following tests of Portland cement are required for important works :

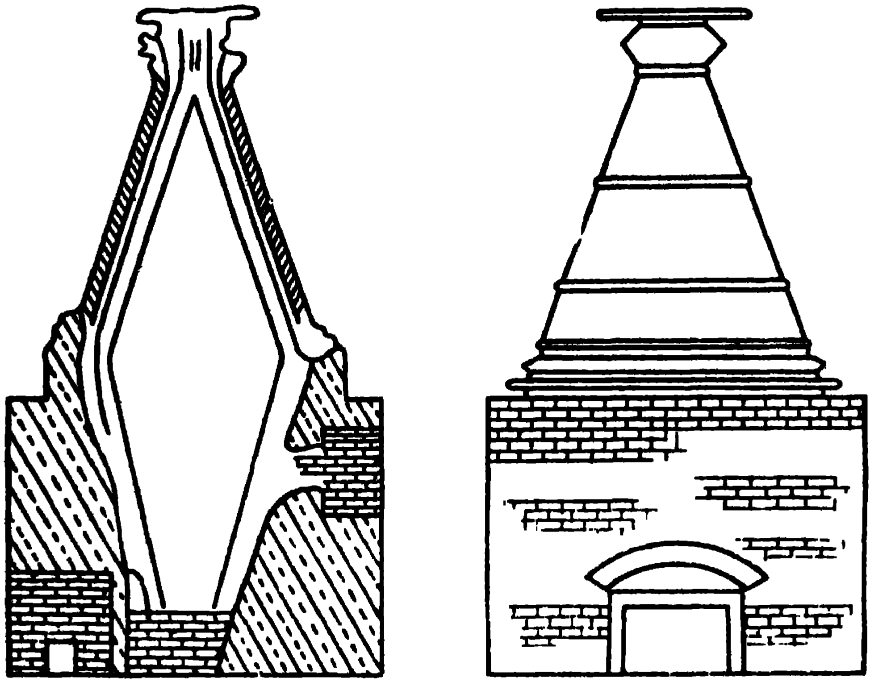
1. *Fineness—Sieve test* : Residue on I.S. sieve No. 9 should not exceed 10%.

*Surface area test*—Ordinary cement has a specific surface roundabout 2,250 sq. cms. per gram but in case of high strength cement it is 3,250 sq. cms. per gram.

2. *Weight*—It varies from 1,200 to 1,800 kg/m$^3$ according as it is overburnt or underburnt.

3. *Colour*—It should be grey or greenish grey colour but it cannot be relied on the colour test only.

4. *Setting*—Ordinary cement shall have an initial setting time of not less than 30 minutes and a final setting time of not more than 10 hours. Quick-setting cement shall have an initial setting time of not less than 2 minutes and a final setting time of not more than 30 minutes. Setting is tested by Vicat's Needle Apparatus (Fig 3.5).



Section Elevation

Fig 3.4 Bottle-shaped Intermittent kiln

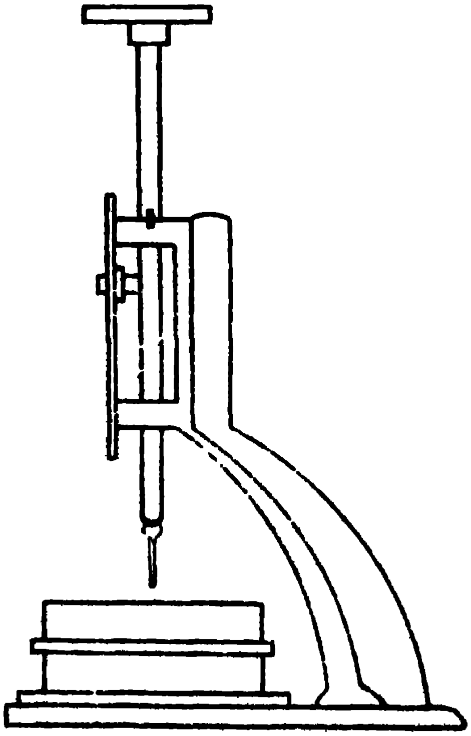


Fig 3.5 Viçat's needle apparatus

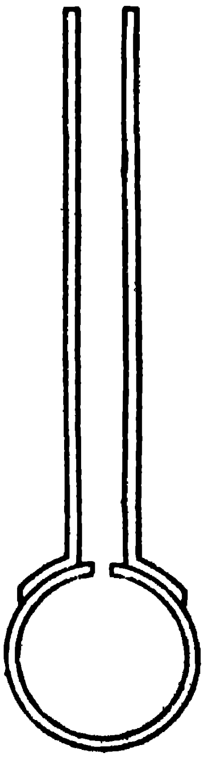


Fig 3.6 Le Chatelier apparatus

5. *Soundness test*—Cement containing free lime and magnesia will hydrate slowly and so the mortar and concrete prepared with such cement is liable to expand and crack after sometime. In soundness test 'Le Chatelier' apparatus (Fig. 3.6) is used.

6. *Tensile test*—This is tested by making briquettes of cement and sand (1 : 3) and subjecting them to tension in the tensile testing machine (Fig. 3.7). Briquettes of cement and sand (1 : 3) after 7 days' immersion (average of 6 briquettes) should bear on an average a tensile stress not less than 25 kg/cm$^2$.

7. *Compressive strength*—This is tested by making cubes of cement and sand (1 : 3) of 7 cm size and subjecting them to compression. Cubes (average of 6 briquettes) after 7 days' immersion should bear a compressive stress not less than 175 kg/cm$^2$.

8. *Test for chemical composition*

(1) Cementation Index—Proportion of lime to silica, alumina and iron oxide i.e. $\dfrac{CaO}{2{\cdot}8\, SiO_2 + 1{\cdot}2\, Al_2O_3 + {\cdot}6\, Fe_2O_3}$ must be between 1·02 and 0·66.

(2) Insoluble residue not to exceed 1.5%.

(3) Sulphur content not to exceed 2·75%.

(4) Magnesia not to exceed 5%.

(5) Loss on ignition not to exceed 4% in temperate climate and 4% in tropical climate.

3.17.4 *Vicat's Needle Apparatus* (Fig. 3.5). This is generally used for finding out setting time of cement.

*Instructions for use*—Gauge about ·4 kg of neat cement with correct quantity of water, mix it thoroughly and quickly into a stiff paste and with this fill through the larger end of the circular brass mould of 4 centimeters in height resting on a glass plate. The ring is then placed upside down on a glass plate and placed below the needle. The index should be read and recorded when the needle rests on the glass plate. The set is said to have commenced, the moment the standard needle is not able to penetrate completely to the bottom of the paste and the cement is said to be set hard when the needle does not leave an impression on the paste. The interval from the time of gauging to the time till the beginning of setting hard is noted as setting time.

3.17.5 *Le Chatelier Apparatus* (Fig. 3.6). The test mould, which is a split cylinder of diameter and depth each 30 mm, is filled with neat

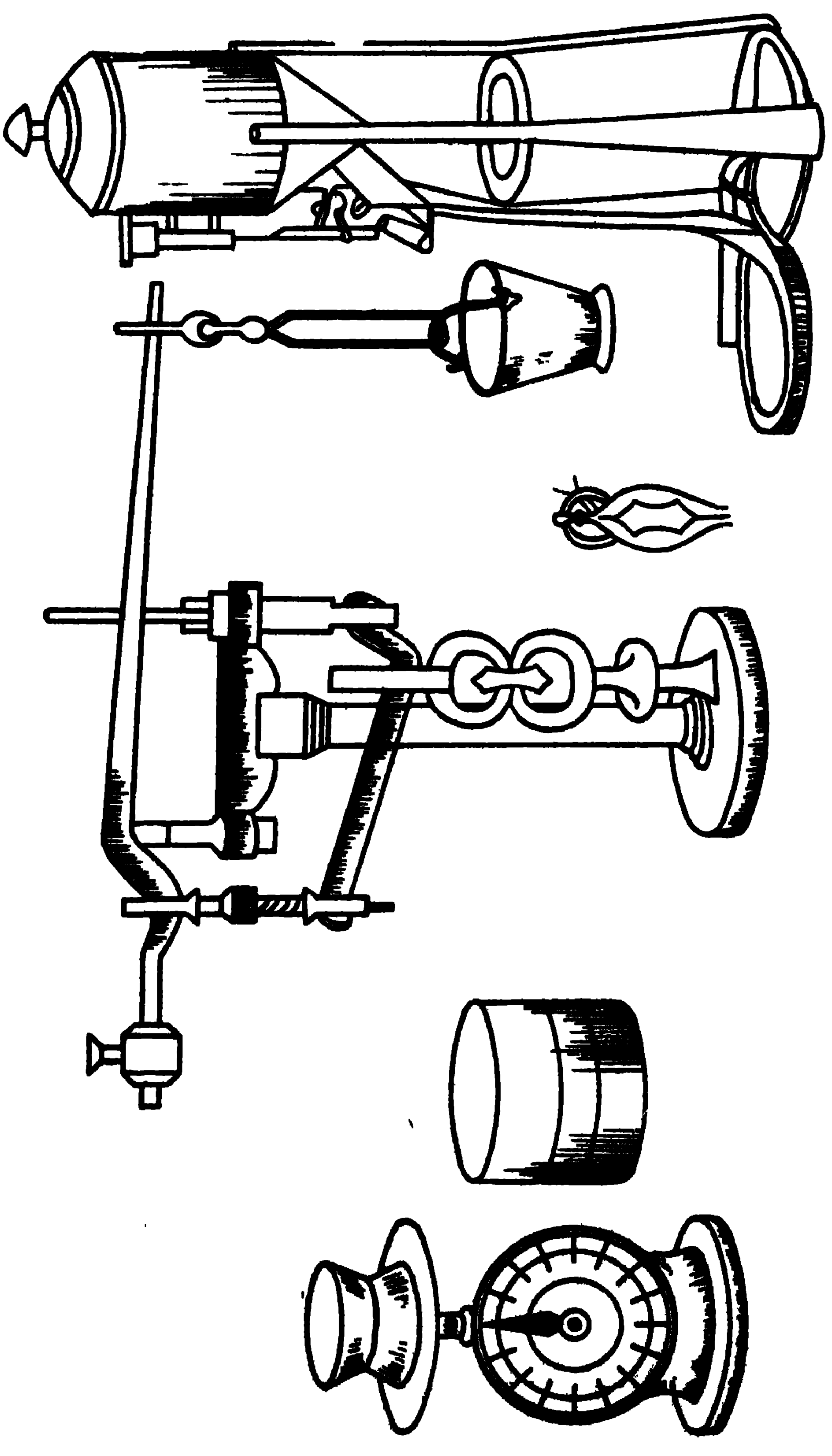


Fig 3.7 Michaelis's compound lever machine

cement paste properly gauged with water. It is cured for one day at about 15·5°C. Distance $d_1$ between the pointers is noted. The mould is then submerged in water which is brought to boiling point steadily in about half an hour and it is kept boiling for one hour and is then cooled to the room temperature. Distance $d_2$ between the pointers is measured again. $d_2 - d_1$ indicates the expansion of the cement under test and this should not be more than .4 in. *or* 10 mm. Length of pointer is 165 mm.

3.17.6 *Michaelis's Compound Lever Machine* (Fig. 3.7). It is used for testing the tensile strength of cement. It consists of a cast iron pillar which carries two levers, one being 1 to 5 and the other 1 to 10 making a total leverage of 1 to 50. The counterpoise is for adjusting lever to its correct position shown by the upright guard.

The briquettes are made either of neat cement or of cement and sand in desired proportion. Briquettes of 3·8 cm square sectional ard at the middle are made in moulds and placed under water after 24 hours. These are tested three or six at a time after 1 week, 2 weeks, 3 weeks, 1 month, 2 months, etc. up to one year and the average value of three or six is noted. Now-a-days briquettes of 2·54 cm sp. sectional area at the middle are tested.

The briquette is placed in position in clips by adjusting the lower one. Shots are poured into the can from the automatic shot run when the briquette is being tested. When the specimen fractures the shots automatically cut off by a trigger operated be the sudden fall of the steelyard with can. The receiving can is then unhooked and placed on a specially calibrated spring balance which gives the load in kg at which the specimen was fractured.

3.17.7 *Breaking Tensile Strength of Portland Cement.* Sectional area of briquette at fracture = 15 cm².

| The immersea in water | Net cement kg | C : S 1 : 1 kg | C : S 1 : 2 kg |
|---|---|---|---|
| 1 week | 210 | 68 | 32 |
| 1 month | 308 | 150 | 78 |
| 3 months | 400 | 250 | 210 |
| 12 months | 490 | 362 | 276 |

From the table it is clear that the strength of cement increases greatly with the age of immersion and also when the proportion of sand is less.

### 3.17.8 *Indian Standard Specification for Cement.*

1. *Fineness by sieving*—The cement should comply with the following :

| | *Ordinary* | *Rapid hardening* |
|---|---|---|
| After sieving, the residue by weight on I.S. Test Sieve No. 9 *not to exceed* | 10% | 5% |

2. *Soundness by Le Chatelier method*—Expansion of any cement should *not exceed* 10 mm.

3. *Setting*—

| | *Ordinary* | *Rapid hardening* | *Low heat* |
|---|---|---|---|
| (a) Initial setting time *not less than* | 30 mins. | 30 mins. | 1 hr. |
| (b) Final setting time *not more than* | 10 hrs. | 10 hrs. | 10 hrs. |

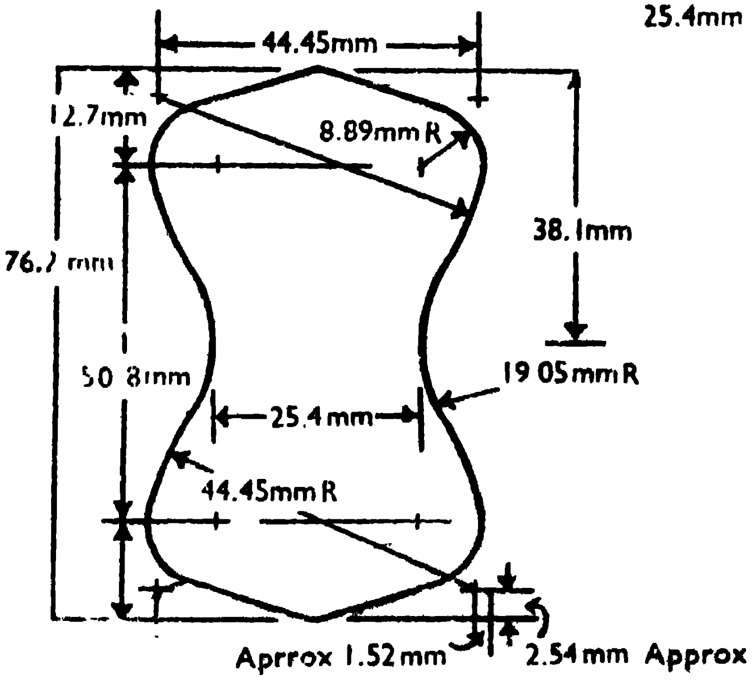


Fig. 3.8 Dimensions of standard briquette

4. *Tensile strength of cement mortar (1 : 3)*

*Standard briquette*

Front and side views of Indian Standard briquette of cement mortar (1 : 3) for testing tensile strength are shown in the diagram.

The average strength of six briquettes moulded with cement mortar (1 : 3) is as follows :

| | *Ordinary* kg/cm$^2$ | *Rapid hardening* kg/cm$^2$ |
|---|---|---|
| (a) After 1 day, *not less than* | — | 20 |
| (b) ,, 3 days, ,, ,, ,, | 20 | 30 |
| (c) ,, 7 days, ,, ,, ,, | 25 | — |

No tensile strength is necessary for low-heat cement.

**3.17.9** *Compressive Strength of Cement Mortar (1 : 3).* The average strength of three 7·06 cm cubes made by gauging 185g of cement with 555g of standard sand and 74g of water is as follows :

| | *Ordinary* kg/cm$^2$ | *Rapid hardening* kg/cm$^2$ | *Low heat* kg/cm$^2$ |
|---|---|---|---|
| (a) After 1 day, *not less than* | — | 115 | — |
| (b) ,, 3 days, ,, ,, ,, | 115 | 210 | 70 |
| (c) ,, 7 days, ,, ,, ,, | 175 | — | 115 |
| (d) ,, 28 days, ,, ,, ,, | — | — | 265 |

**3.17.10** *Chemical Requirements.*

(a) Ratio of lime to silica, alumina and iron oxide $\ngtr$ 1·02 and $\nless$ 0·66%.

(b) Ratio of alumina to that of iron oxide $\nless$ 0·66 %.
(c) Weight of insoluble residue $\ngtr$ 1·5%.
(d) Weight of magnesia $\ngtr$ 5%.
(e) Total sulphur content $\ngtr$ 2·75%.
(f) Total loss on ignition $\ngtr$ 4%.

**3.17.11** *Rough and Ready Methods of Examining Cement.* The tests described above are to be conducted in the laboratories. The following are a few rough and ready methods of testing cement :—

1. When hand is plunged into a bag or cask of cement, it should feel cool but not warm.

2. A thick paste of Portland cement with water on a piece of thick glass, kept under water for 24 hours, should not crack but set.

3. A block of cement 2·5 cm × 2·5 cm × 20 cm long after seven days' immersion placed on supports 15 cm apart should not show signs of failure when weighed with 34 kg.

4. A handful of cement thrown into a bucket of water would not float but sink.

3.17.12 *Varieties of Cement.* The following are the varieties of cement in common use :

1. Normal-setting cement (Portland cement)
2. Rapid-hardening cement
3. Quick setting cement
4. Low-heat cement
5. Blast furnace cement
6. High alumina cement (Cement fondu)
7. White cement (Snowcrete)
8. Coloured cement (Colourcrete)
9. Pozzuolana cement
10. Sulphate resisting cement.

The high strength of *rapid hardening cement* is due to finer grinding, burning at a higher temperature and increased lime content in composition. Fineness of grinding and a small percentage of aluminium sulphate accelerate the setting action of *quick setting cement* which is advantageous when concrete is to be laid in water. In *low heat cement* the heat of hydration is reduced by reducing the tri-calcium aluminate contents otherwise irregular cracks may occur due to shrinkage when the mass cools to a temperature below that attained during the setting. For *blast furnace cement* granulated slag is intimately mixed with cement clinker and durable cement is obtained. ***High alumina cement*** is manufactured by melting a mixture of bauxite and lime and grinding the clinker and this is rapid hardening cement. The whiteness of normal setting cement is secured by reducing the iron oxide to minimum and it is sold under the trade name of ***Snow-crete***. ***Colourcrete*** is produced by mixing intimately mineral pigments with ordinary cement. ***Acid-resisting cements*** are silicate-base cements.

3.17.13 ***Cement with Additives.***

(i) ***Air entraining cement***—To improve workability of cement with smaller water cement ratio a number of indigenous air entraining agents such as resins, sodium salts of sulphates, glues and fatty acids are added during grinding. The amount of air entrained depends upon the type and grading of the mix, aggregate and other factors. Increase in entrained air beyond 6% causes reduction of compressive strength beyond permissible limits. Apart from improving workability air entrainment improves frost resistance of concrete and reduces segregation and bleeding of the mix.

(ii) *Pozzolanic Cement*—It is prepared by grinding Portland cement clinker and pozzolana or by mixing hydrated lime. It may be noted that although, pozzolana in itself being a siliceous material does not possess cementing properties but in finely powdered form and in the presence of water it reacts with lime to form compounds having cementing properties. Pozzolanas are added to cements when the aggregate used for the manufacture of cement is known to be reactive. Free lime liberated during hydration of cement disrupts the concrete while pozzolanas react with the free lime and prevent disruption. Similarly harmful effect of alkali aggregate reaction is counteracted by pozzolanas. Pozzolana cement is specially useful in marine, hydraulic and underwater construction.

(iii) *Hydrographic cement*—In order to prevent cement getting spoiled on account of humid conditions or due to long storage, hydrographic cement is prepared by mixing water repelline chemicals during grinding of the clinker into fine powder.

The hydrographic cement also entraps certain proportion of air bubble and thereby improves workability which results in reduction of water cement ratio and higher strength.

**3.17.14** *Selenitic Cement.* It contains on an average 5% of sulphate of lime which is mechanically mixed and ground with lime or cement. It is quick-setting and takes higher proportion of sand. Selenitic is scientific name of gypsum.

**Cement for use in sea water**

It should be rich in silica and as poor as possible in alumina and ferric oxide because aluminate and ferrate of lime are decomposed and softened by sea water while cement rich in silica resists the action of sea water. Sulphate resisting cement is used for structures in sea. Some cements are unsuitable for marine work on account of the high proportion of alumina and ferric oxide and low percentage of silica in them.

**3.17.15** *Storing Cement.* Portland cement is put in casks of 0·1 m$^3$ for transportation and in sacks of ·05 m$^3$ capacity for local use. The following precautions should be taken in storing cement especially when in sacks :

1. It should be stored for the shortest period possible but not at all in the rainy season.

2. It should be kept in a weather-tight room.

3. Damp godowns and floors should be avoided,

4. It should not be stored against walls but should be 0·6 m away from walls.

5. It should be stored in close formation and covered over with tarpaulin so as to prevent circulation of air through the stock.

6. Not more than ten cement bags should be stacked one over another as due to heavy load air-setting takes place in bags in lowest layers.

400 bags of cement can be stacked in 4 rows, 10 in a raw, 10 layers deep in each stack. 4·5 m × 2·5 m × 2 m high a shed of size 6 m × 3·5 m is enough to store 20 tons.

Manufacturers store cement in silos satisfactorily. It will be a good plan for big construction work to arrange for the delivery of cement from manufacturers in small fortnightly or weekly consignments spreading over the period of construction.

**3.17.16** *Use of Cement.* Cement is used in following cases :

1. In foundation, in wet places and in all kinds of structures exposed to the action of water, such as, wet foundations, reservoirs, water tight floors, dock yards, etc.

2. For important structures where great strength is required, such as, bridge piers, light houses, lofty towers, etc.

3. For the most exposed parts of structures, such as, tops of chimneys, coping of compound walls, bridges, etc.

4. For making cement mortar and concrete, reinforced concrete, reinforced brickwork, artificial stone, etc.

5. In drainage and water supply works.
6. For protecting outer faces of structures from weather.
7. For thin walls which require extra strength.
8. For pointing.

Mortar or concrete made from cement should be mixed in small quantities at a time as required for use, as the cement begins to set just after mixing with water.

3.17.17 *Adulteration of Portland Cement.* Iron slag, river clay, etc. are used for the adulteration of Portland cement. Slag mixed cement should be rejected as lime present in slag may disintegrate in the work and cement containing river clay will set very poorly.

3.17.18 *Natural Advantages of Cement Industry in India.* Limestone of excellent quality exists in abundance near railway lines throughout India. Factories are established in the vicinity of the limestone quarries. Suitable clay is also available in abundance close to the works. Gypsum is produced in India but has to be brought from a distance and it is only 5% of the output of cement and costs only Re. 1/- per tonne of cement. The employment of high skilled labourers from abroad is not absolutely necessary. As regards fuel, cement industry in India has no natural advantage because factories are at a great distance from coal fields and so the freight on coal is a very heavy item in the cost of the production of cement. The principal market for cement is not in local consumption but in great ports, such as, Calcutta, Bombay, etc. which are at a great distance from the factories.

**Cement Makers in India and their trade marks or brands**

| | *Makers* | *Brands* |
|---|---|---|
| 1. | The Indian Cement Co. Ltd., Porbandar (Bombay) | Ganpati |
| 2. | The Kanti Cement & Industrial Co. Ltd., Katni (C.P.) | Castle |
| 3. | The C.P. Cement Co. Ltd., Kymore (C.P.) | Swastika |
| 4. | The Bundi Portland Cement Ltd., Lakheri (Bundi) | B. B. B. |
| 5. | The Gwalior Cement Co. Ltd., Banmore (Gwalior) | Sun |
| 6. | The Punjab Portland Cement Ltd., Wah (Punjab) | Five Rivers |
| 7. | The Okha Cement Co., Ltd., Dwark (Bombay) | Anchor |
| 8. | The Okha Cement Co. Ltd., Dwarka (Bombay) | Horse Head |
| 9. | The Shahabad Cement Co. Ltd., Shahabad (Bombay) | Char Minor |
| 10. | The Stone Valley Portland Cement Co. Ltd., Japla (Bihar) | Rohtas & Rohtacrete |

## III. SAND

3.18 *Sand* is a form of silica ($SiO_2$) and may be argillaceous, siliceous, or calcareous according to its composition. Natural sands are the weathered and worn out particles of rocks and are of various grades or sizes depending on the amount of wearing. The grains of sand may be sharp, angular, or rounded.

3.18.1 *Natural Sources of Sands and their Classification.* It is usually obtained from pits, shores and beds of rivers and seas. There are three kinds of sands in use :

1. *Pit sand.*
2. *River sand.*
3. *Sea sand.*

1. *Pit sand* is sharp, angular, porous and free from salts rendering it most suitable for mortar. Clay and other impurities in it should be screened and washed. Fine pit sand should not leave any stain on the fingers when rubbed between them. Large grained sands are usually better than small grained ones. The light-brown or yellowish sharp grained *Mogra sand* used in Calcutta in pit sand.

2. *River sand* is fine, round and polished due to rubbing under the action of water current, and so its adhesive value is reduced. River sand containing earthy impurities, gravels, etc. must be screened and washed. It is more white in colour, globular and smaller in size than pit sand and so it is suited for plastering.

3. *Sea sand* is also fine, round and polished due to rubbing under the action of water current. But it is the worst of the three and should not be used for mortar or plastering as it contains sea salts which attract moisture from the atmosphere causing permanent dampness and efflorescence and thereby the work gradually disintegrates.

3.18.2 *Standard Sand.* It passes through a sieve No. I.S. 480 and is retained on a sieve No. 15

**Examination of sand**

Clean sand should leave no stain on moist fingers when rubbed between them. Presence of salts may be easily detected by taste, the sharpness of grains by the feel and size roughly by the eye. There are chemical tests and mechanical analysis of sand, but these are elaborate methods.

3.18.3 *Requisites of Good Sand.* The sand should be ***sharp***, ***clean***, and ***coarse***, and grains should be of durable materials and the various sizes or grades of grains should be such as to give the minimum void.

3.18.4 *Effect of Clay in Sand.* It varies with the richness of the mortar. The fine clay helps to fill the voids of sand and causes the cementing material to bind the grains more strongly when the proportion of sand is more than that of cementing material. But when proportion of sand is less the presence of clay retards the setting of the cement and makes the mortar weaker.

3.18.5 *Treatment of Sand before Use.* Sand containing lumps or small stones should be screened or sieved when greater fineness is required. Sand containing earthy impurities. such as, clay, loam, etc. should be thoroughly washed by being well stirred in a trough under a current of water, which carries away the impurities. Pure sand is left in the trough when clear water flows out from the trough. It is sometimes washed by machinery.

3.18.6 *Void in Sand.* The amount of cement required will be less when void in sand is less, and then sand will be more economical. The percentage of void may be practically determined as follows :

Put wet sand in the measured vessel of 100 $m^3$ in capacity up to top level, and then pour water gradually from a measured reservoir until the vessel is full to the brim. Then the measured water put into the vessel is the percentage of void in sand.

3.18.7 *Moisture and Bulking of Sand.* There is a steady increase in the volume of sand to about 25% up to about 5% of the moisture present in sand. It may be experimented by taking dry sand of known volume in a measuring glass and adding small quantity of water successively. It will be noticed that each time there is an increase of volume up to about 5% of moisture. *Bulking of sand* for small moisture content is due to sand grains getting covered with a film of water, which prevents them from coming in contact with one another. But bulking decreases rapidly with the addition of water beyond 5% and the volume of sand saturated with water is found to be equal to that of dry sand. So allowance should be made for the apparent bulking while measuring moist sand by volume in the preparation of mortar or concrete. It is also noted that bulking is more with fine sand than for coarse sand. If the bulking of sand with 5% moisture be 25% then for 1 $m^3$ of dry material 1·25 $m^3$ of wet sand will be required otherwise cement used will be more.

3.18.8 *Selection of Sand for Use.* Before the commencement of an important work all available sands and their substitutes should be tested for use in mortar as follows :

1. Sieve analysis should be made to determine the various sizes and grades of sand to make good mortar. Sometimes sand is

improved by screening out some coarse sand or by adding coarse or fine sand.

2. The percentage of void is also to be found out

3. Presence of salt is detected by taste.

4. Tests should be made so as to see whether sand improves by washing or not.

5. Tensile tests by briquettes made of mortar of different proportions with age should be made.

Compare all the available sands and their substitutes as regards strength, durability, and cost. It may be economical in the long run to pay more for transport of good sand than to use inferior local sand, or it may be more economical to use local sand with higher proportion of cement than to pay the transport of good sand. The engineer on the spot will select the desired sand.

3.18.9 *Fineness Modulus of Sand.* Fineness modulus of a particular sand is an index of its coarseness or fineness. The number is roughly proportional to the average size of the particles in sand. The sum of the cumulative percentages by weight of the material retained on I.S. Sieve No. 480, 240, 120, 60, 30 and 15 and dividing the sum by 100 gives the fineness modulus of sand as explained below :

| I. S. Sieve | Percentage retained | |
|---|---|---|
| | Natural sand | Crushed stone sand |
| 480 | 2 | 4 |
| 240 | 10 | 20 |
| 120 | 35 | 35 |
| 60 | 75 | 80 |
| 15 | 95 | 95 |
| Fineness Modulus | $\frac{272}{100} = 2{\cdot}72$ | $\frac{294}{100} = 2{\cdot}94$ |

The index is used for specification and for controlling grading. The grading may be done as below :

| Sand | Fineness Module |
|---|---|
| Fine | 2·20 — 2·60 |
| Medium | 2·60 — 2·90 |
| Coarse | 2·90 — 3·20 |

**3.18.10** *Use of Sand.* It is largely used in mixing mortar, concrete, plaster, etc. Fine sand should be used for plasterers' work and moderately coarse sand for brick-layers' work.

**3.18.11** *Function of Sand in Mortar.* (1) Sand in mortar does not add to its strength but is used as an adulterant for economy. (2) It prevents the shrinkage and cracking of mortar in setting. (3) It adds a hard ingredient and thus gives greater strength to mortar against crushing

**3.18.12** *Substitutes for Sand.* Stone screenings, burnt clays, cinders from coal or coke dust, etc. are sometimes used as a substitute for sand in making mortar. These are cheap and not liable to the action of saltpetre.

*Stone screenings* are fine particles screened out of crushed stones. The greater strength of mortar made with them is due to their greater sharpness.

*Burnt clay* should be fine, stiff and thoroughly burnt. It is porous and so absorbs moisture. Mortar made with it will crack and shrink during drying and so it is not used for waterproof walls.

*Scorioe* from iron works, *clinkers* from brick kilns, and *cinders* from coal or coke dusts make good substitutes for sand when quite clean and properly used. It is cheaper and sets quickly due to sharpness of grains. It makes a black mortar. Mortar is stronger when it is mixed with ghooting lime than fat lime. But *wood cinders* are alkaline and *crushed slag* containing lime from the furnace should not be used at all.

## 3.19 Surki

*Surki* is finely powdered burnt clay and generally made from slightly underburnt or pila bricks. Good surki should be perfectly clean and free from any admixture of foreign substances and residue on I.S. sieve No. 9 shall not exceed 10 per cent by weight.

It has been noticed that different quality of clay have different temperatures of becoming at which they produce more satisfactory surki, these temperatures are, however, different from the temperature at which best bricks will be produced. It is, therefore, advisable to burn clay to predetermined temperature for production of surki instead of powdering slightly underburnt bricks.

3.19.1 *Functions of Surki in Mortar.* 1. Like sand surki is used in mortar as an adulterant for economy. 2. Unlike sand surki gives strength and hydraulic property to the mortar.

3.19.2 *Use of Surki.* It is largely used in mixing mortar, concrete, plaster, etc.

## 3.20 Mortar

*Mortar* is a paste generally made by mixing cement, sand and water, or lime, sand or surki and water, or cement, lime, sand and water. The soft paste absorbs carbonic acid gradually from the atmosphere and hardens into a compact solid body after a short time.

The properties required of a good building mortar are as follows :

1. The mortar should be easily workable.
2. It should set quickly to ensure the speed of construction.
3. It should develop sufficient strength for the work for which it is used in compression, tension and bond.
4. It should bind the bricks to give a tight joint through which water cannot penetrate.
5. It should be durable and should not affect the durability of other materials.

The workability of a mortar is determined by its water retentivity and good trowelling properties. Cement is a water repeller and lime is a water retainer. Good workability of a mortar can be obtained by using lime. The higher the proportion of lime used the better are the workability of the mortar. Even a rich cement mortar (1 : 2) is inferior to lime mortar or lime cement mortar in this respect.

Mortars made of non-hydraulic lime and sand set very slowly. Today with tempo of fast work this specification of mortar is a lag and so cement has to be used with non-hydraulic lime. Simple cement and sand mortar is found to be a misfit. So the combination of cement and lime is the proper solution. This *combination mortar* will answer to the mortar requirements 1 to 5 above. Admixture of cement will be a mistake in case of hydraulic lime.

Safe strength of a brick wall depends on three factors—1. Ultimate crushing strength of bricks, 2. Strength of mortar, and 3. Slenderness ratio of the wall. When slenderness ratio is same, the safe strength is found out by the quality of bricks and mortars.

3.20.1 *Table of max. permissible compressive stress on walls of bricks when slenderness ratio does not exceed* $10\tau/m^2$.

| Mix of mortar | Cement<br>Lime<br>Sand | 1<br>¼<br>3 | 1<br>¼<br>4 | 1<br>1<br>6 | 1<br>2<br>9 | 1<br>3<br>12 |
|---|---|---|---|---|---|---|
| Crushing strength of bricks ($kg/cm^2$) | 105 | ·7 | ·63 | ·63 | ·56 | ·42 |
| | 210 | ·91 | ·84 | ·84 | ·77 | ·56 |
| | 315 | 1·12 | 1·03 | 1·05 | ·98 | ·84 |
| | 350 | 1·54 | 1·40 | 1·26 | 1·12 | ·91 |
| | 525 | 2·24 | 1·61 | 1·54 | 1·54 | ·91 |
| | 700 | 2·8 | 1·89 | 1·54 | 1·54 | ·91 |

It will be clear from the table that with the available bricks in India whose crushing strength does not exceed 210 $kg/m^2$, there is little difference in strength between a brickwork of 1 : 3 mortar and 1 : 2 : 9 *combination mortar.*

3.20.2 *Use of Mortar.* Mortar is used (1) to bind together the bricks or stones in brick or stone masonry, (2) to give a soft even bed between the different layers of brick or stone masonry for equal distribution of pressure over the bed, (3) to fill up the spaces between bricks or stones for making wall weathertight, (4) in concrete as a matrix, (5) in pointing and plastering to protect the joints and surfaces of brick and stone masonry, (6) for moulding purposes and also to improve the appearance.

3.20.3 *Function of Sand and Surki in Mortar.* Sand in mortar does not add to its strength but is used mainly as an adulterant for economy, and also prevents shrinkage and cracking of mortar in setting.

Like sand surki also is used as an adulterant but unlike sand, surki gives strength and hydraulic property to the mortar.

3.20.4 *Classification of Mortar.*

(1) **Lime mortar**—a mixture of lime, sand and water.

(2) **Surki mortar**—a mixture of lime, surki and water.

(3) **Lime, sand, surki mortar**—a mixture of lime, sand, surki and water.

(4) **Combination mortar**—a mixture of cement, lime, sand and water.

(5) **Cement mortar**—a mixture of cement, sand and water.

(6) **Mud mortar**—a mixture of puddle mud and water.

Sand should be sharp, angular, porous, and free from salts and other impurities. Surki should be perfectly clean, free from any admixture of foreign substances and pass through a sieve of I.S. No. 9. Water used in mixing mortar should be free from mud, clay or other impurities. Lime must be well slaked, and cement must be fresh and free from adulteration.

3.20.5 *Composition of Mortar.* It depends upon, the purpose for which it is used. Fat lime mortar does not set hard inside thick brickwork and has no hydraulic property. Such a mortar (lime : sand : : 1 : 2) is suitable only for the joints in thin brickwork. In important engineering works and in foundations, either cement mortar or hydraulic lime mortar (1 lime : 2 sand) may conveniently be used according to the strength of lime or nature and importance of the work for which it is meant. A pure hydraulic lime without any admixture of sand or 1 kankar lime to 1 surki or 1 kankar lime to 1¼ sand may be used when great strength or hydraulicity is required. Surki mortar (1 fresh stone lime : 2 surki or 1 fresh stone lime : 1 surki and 1 sand) is often used in foundation and superstructure of simple structures. Cement mortar is in various proportions from 1 : 2 up to 1 : 6. Cement mortar (1 cement : 6 sand) is strong enough for ordinary structures, but mortar (1 cement : 2 sand) is the best and is used for important structures. Mud mortar is used for small shed and temporary structures. For stone masonry lime mortar (1 hydraulic lime : 2 sand) or cement mortars of various proportions are used as surki mortar does not adhere well to stone masonry.

3.20.6 *Mortar Mixing. Lime or surki mortar or ordinary mortar*—The heap of slaked lime covered with sand or surki in definite proportions taken by volume and not by weight should thoroughly be mixed dry until it is of one uniform colour throughout. Then the mixture is shovelled into the trench of the *country mortar mill* (Fig. 3.9), enough water being added to bring the mixture to the required consistency. The stone roller revolved in the trench by a pair of bullocks grinds the mixture, and the grinding must continue for at least six hours before it can be considered fit for use. When the ingredients are thoroughly mixed and ground, the mortar is shovelled out of the trench on a platform, for use on the works. On extensive works a mortar mill similar to a surki mill is generally used. On very small works the mixing is done by hand by being pestled with a 'phora' in a trough or 'tagarh' made of loose brick flooring and bricks on end at the edges. It is divided into two compartments. The ingredients in proper proportions by volume is first mixed dry and then mixed by gradually adding water and then left for the night for tempering. Care should be taken so that the prepared mortar does not harden or get dry before use. When mortar from one compartment is used for the work, sand or surki is spread uniformly in the other with proportionate quantity of lime spread over it for the use of next day. Mortar which has set partially before use, must on no account be used in any work whatsoever.

*Evils of fat lime mortar*—If pure lime mortar be used in massive masonry work, only the outer edges of the joints set due to the action of carbonic acid in the air but mortar inside the wall remains soft. Due to this, heavy pressure is thrown upon the outer edges of masonry and they become flushed and sometimes the faces of the walls become liable to fall away. This weak mortar retains moisture which when freezes also throws off the outer crust.

3.20.7 (a) *Cement Mortar*. Cement and sand in definite proportions by volume are carefully turned over together until the mixture is of one uniform colour, before required quantity of water is added. Again the mixture is turned over once or twice for uniform mixing. Care should be taken that too much water is not added and it is used as soon as possible, before initial setting of cement commences.

(b) *Mud Mortar*. Sticky clay is puddled or pugged with water until it comes to the required consistency. It is called 'gara' and frequently used for economy in temporary works not exposed to the action of water. It is used in kacha pucca works. Masonry in good mud mortar can stand a safe pressure of 16 tonnes/m$^2$.

3.20.8 *Bulk of Mortar Produced*. The bulk of wet mortar in proportion to that of its dry ingredients differs generally as regards the nature of lime or cement and the quality and quantity of sand or surki mixed with it. Hydraulic lime or cement produces a smaller amount of wet mortar than that of pure lime. as hydraulic lime or cement expands less in slaking. The wet surki mortar is about $\frac{2}{3}$rd of the dry mixture. For 100 $m^3$ of brickwork mortar is made by mixing 24 $m^3$ of dry surki and 12 $m^3$ of dry lime with water to tough paste.

| Fat lime | Portland cement | Sand | Surki | Wet volume | Percentage reduction |
|---|---|---|---|---|---|
| 1 | | | 2 | $1\frac{7}{8}$ | 37 |
| 1 | | 2 | | $2\frac{1}{8}$ | 27 |
| | 1 | | | $\frac{28}{32}$ | 13 |
| | 1 | 1 | | $1\frac{7}{18}$ | 21 |
| | 1 | 2 | | $2\frac{1}{16}$ | 31 |

3.20.9 *Use of Sugar or Molasses in Mortar.* The bad quality of rich lime is corrected to some extent by mixing with it a small quantity of coarse sugar or molasses dissolved in water. Such well prepared mortar will resist the action of weather for centuries. It is found that the addition of pure sugar between $\frac{1}{4}$th and 2 per cent to Portland cement increases its strength to a large extent after 3 months. Sugar retards setting action but chemical action takes place more perfectly. Cement is useless when it contains more than 2% of sugar.

**3.20.10** *Selenitic Mortar.* It is made by mixing selenitic cement and sand to the required proportions.

**3.20.11** *Pozzuolana Mortar* It is made by adding required proportion of pozzuolana to fat lime mortar so as to make up the deficiency of clay.

(i) *Surki Mortar*—Similar to lime mortar except that in place of sand specified quantity of surki is mixed. Surki imparts hydraulic property to lime and such mortar should therefore be used within 24 hours of being grounds.

(ii) *Lime-Cinder, Lime-Surki Sand and Lime-Sand-Cinder Mortars*—Similar in the method of mixing and prepared as lime mortar.

3.20.12 *Mixture of Lime and Cement.* Bad lime is improved by adding Portland cement to it when required.

**Composite Mortars :**

*Cement Lime Mortar*—When it is required to impart setting property to fat lime mortar small quantities of cement are mixed so that the mortar to which cement has been added is utilised in work within two hours of addition of cement. For example of 1 : 2 : 9 composite mortar is required, lime and sand in the proportion of 1 : 4½ by volume is prepared and as and when required 9 volumes of this are added with one volume of cement immediately before use.

The plasticity and workability of mortar is improved of hydrated lime used for mortars is soaked overnight for 24 hours before being used in the mortar.

3.20.13 *Grout.* It is a very thin liquid mortar used to fill empty joints, left in consequence of bad workmanship, by pouring it over courses of masonry. It is deficient in strength and so should not be used when it can be avoided.

3.20.14 *Strength of Mortar.* Lime or cement is much more expensive than surki or sand. .So it is economical to use as much sand or surki to it without unduly weakening the strength of mortar. Stronger mortar adds to the strength of the wall but it is hardly economical to make the strength of mortar joints greater than that of bricks or stones to be jointed. It should be so strong as to produce an equality of resistance which will compel the fracture to break the material of the wall straight across rather than along joints.

3.20.15 *Tests of Mortars.* Mortars are tested with an object of determining their (1) hardness, (2) resistance to crushing, (3) adhesiveness to bricks or stones, (4) cohesion or tensile strength, (5) time they take to set, and (6) the quantity of sand or surki which may safely and economically be used in their composition.

3.20.16 *Precautions in Using Mortar.*

1. In using mortar, the bricks or stones to be jointed together should be soaked in water for at least 12 hours before they are to be used so as to prevent the absorption of moisture from the mortar before it has time to set,

2. Mortar should be as stiff as it can be used without inconvenience ; the joints should be well filled ; grout should never be used except in cases where from the position of the joint it cannot be filled well by the usual mortar of proper consistency.

3. Work made of mortar should be kept wetted for a week or two after it has been laid so as to prevent the rapid drying of mortar especially in hot weather.

4. Mortar before setting is damaged by frost. When frost is expected, foundation and plinth should be laid in quick-setting hydraulic mortar as the action of frost is severe at and near ground level. During severe frost construction should be stopped if possible.

5. Mortar should be placed on a platform or in a tub for use so as to keep it free from dirt. Mortar once hardened by being left long unused should not be used again.

6. Salt water is beneficial to hydraulic lime mortar by preventing too quick drying, but is injurious to pure lime mortar and surki mortar for it causes damp and efflorescence.

7. Fat lime mortar, unless improved by pozzuolana and other substances, is of little or no importance as it is wanting in strength.

A *lean* mortar has a very small proportion of cement and a *rich* mortar has a large proportion of cement. The term *neat* is used when no sand is added to cement.

## 3.21 Plaster

*Plaster* is a thin coat of mortar of different composition, which covers the faces and hides the joints of walls, ceilings, etc. on which it is applied.

3.21.1 *Use of Plaster.* Plaster is used (1) to give a smooth and finished surface to the work, (2) to provide a ground for decoration or white or colour-washing, (3) to cover joints and defective workmanship or unsound and porous brick or stone masonry, (4) to preserve the surface from the action of weather, and (5) for moulding and ornamental works.

### 3.21.2 *Qualities of Good Plaster.*

1. It should adhere firmly to the surface on which it is applied.

2. It should not shrink or contract in volume in drying and setting otherwise it cracks and gives an unsightly appearance.

3. It should not contain unslaked particles of lime and must be fully air slaked. otherwise plaster will blow.

3.21.3 *Classification of Plaster.* Plaster is divided into the following classes :

1. *Lime plaster*, 2. *Surki plaster*, 3. *Cement plaster*, 4. *Sand rubbing*, 5. *Lime punning*, 6. *Stucco plaster*, 7. *Chunam plaster*, 8. *Guniting plaster*, 9. *Mud plaster*, and 10. *Plaster of Paris*.

1. *Lime plaster* consists of lime and sand (usually 1 lime : 2 or 3 sand) mixed with water to form a paste of required consistency. This is tempered and ground in a mortar mill. Sand prevents shrinkage in drying and its substitutes, such as, cinders or coal ashes have that property to some extent. It is 1 to 1·5 cm thick.

2. *Surki plaster* consists of lime and surki (1 lime : 1½ or 2 surki) mixed with water to form a paste of required consistency and is sometimes used in plinths and walls. It is tempered and ground in a mortar mill. It is suitable for surfaces exposed to moisture but is liable to crack when exposed to sun and air. Surki shrinks in drying and so plaster while setting is beaten well for hours with light wooden mallets. To prevent shrinkage sometimes sand is added to surki plaster in the proportion of 1 lime : 1 sand and 1 surki. It is 1 to 1·5 cm thick.

3. *Cement plaster* is an intimate mixture of Portland cement and sand with required water to make a plastic mass. It consists of the usual proportions of 1 cement : 2 or 3 sand though higher proportions, such as, 1 cement : 8 sand is used depending on the nature of work. The ingredients are mixed with water to form a paste of required consistency. It is always laid in single coat. Cement plaster should be kept wet for a week or two after being laid and should be under water for at least 3 days if water can be stored on the plastered surface. It is ·75 to 2 cm thick. Sand is used both for economy and to avoid cracks from shrinkage of cement in setting. Cement plaster is used for reservoirs and structures in contact with water and also for floors, copings, etc.

4. *Sand rubbing*—The outside sand plaster is finished with either sand rubbing or colour-washing. It is a plaster consisting of 1 part of hydraulic lime, 11 parts of pure lime and 22 parts of clean sand and laid ·3 cm thick, thoroughly rubbed, smoothed, and finished.

5. *Lime punning*—The inside sand plaster or lime plaster when thoroughly dry is sometimes finished by a second coat of plaster ·3 cm thick consisting of 1 part of shell lime to 3 parts of stone lime or kankar

lime mixed with water to a fine pulpy mixture. Limes must be thoroughly slaked and tempered by keeping under water for two weeks before use in order to get rid of any heat which would cause it to blow. Limes after being kept under water for some days should be screened through cloths and well mixed. It is applied to previously wetted dry sand plaster with small wooden trowel. It should never be applied on raw sand plaster as it will not adhere easily and moreover the colour of sand plaster will appear through the lime punning. The second coat of plaster in bath rooms up to a certain height is *cement punning*, which is made of neat cement.

6. *Stucco plaster*—In the inside work a very thin coat of plaster known as third coat is sometimes put over the 2nd when dry. It consists of thoroughly slaked and tempered clean white shell lime, whites of eggs, curds, and starch mixed with a little isinglass. It is applied on the surface, rubbed and smoothed with small steel trowel till the surface on which it is applied shines like glass. Palm jaggery, mixed with whites of eggs and clean shell lime, makes a tenacious cement and artificial marble may be produced by mixing colouring matters with it as it takes a very high polish.

7. *Madras chunam plaster* is laid in three thin coats for inside work and it is very expensive. The first coat is a mixture of shell lime and sand tempered with jaggery water and is about 1·5 cm thick. Second coat is a mixture of shifted shell lime and sand without jaggery and is about ·3 cm thick. Third coat which receives the polish is a mixture of whitest shell lime and $\frac{1}{4}$th of its volume of white sand. The thickness of the plaster does not exceed 2 cm.

8. *Guniting plaster* consisting of 1·5 cm fine cement mortar usually 1 cement and 3 sand with minimum amount of water is applied in a continuous stream by compressed air at a pressure of 2·5 $kg/cm^2$ from a cement gun. The gun is held at a distance of about 1 m from the surface to be treated. Cement and sand is loaded in the gun and necessary water is supplied as the mixture issues from the gun. It is largely used in lining tunnels, aqueducts, channels, pipes and cisterns and also in repairing damaged R. C. work for rapidity of execution and strength.

9. *Mud plaster*—Well tempered clay or brick-earth free from lumps, stones, etc, is used for mud plaster. The clay is sifted and thrown into a pit with cowdung and chopped straw in equal proportions. It is then mixed and left for a week with a large quantity

of water to soak and again mixed thoroughly till it comes to the consistency of stiff mortar. This is used especially in temporary sheds, small huts, etc. and at places where there is practically little or no rains.

10. *Plaster of Paris*—It is made by burning and grinding gypsum. It is acted upon by water easily and so not suitable for outside work. It expands during setting and so it is most convenient for repairing holes and cracks. It is not generally used in India as it is very expensive.

3.21.4 *Precautions in Using Plaster*. For exterior work surki should be used instead of sand unless the lime is hydraulic. For works in contact with water, surki plaster or cement plaster should be used. Katni, Sutna, and shell limes must be thoroughly slaked and tempered by keeping under water for at least two weeks before use otherwise it will blister after being laid but Sylhet lime is available as slaked lime. No salt water or sea sand should be used otherwise it will cause efflorescence on structure. The plastered surface to be white-washed or to receive 2nd coat should not be finished with a polish.

3.21.5 *Application of Plaster*. The mortar of the joints of the structure on which plaster is to be applied is raked out to a depth of 2 cm to give a key or hold to the plaster. The surfaces are brushed free from dirt, thoroughly cleaned, and wetted. The required mortar is laid on the structure and rubbed down flat with *wooden trowel* called *'usha'* (Fig. 3.10); then smoothened it with a straight piece of wood called *float* or *'pata'* by passing it in different directions over the surface. The work should be kept wet for at least 3 days after completion. Generally for internal work it is quite sufficient to lay the plaster and smoothen it by passing a float in different directions over the surface. But for external work it must be consolidated with a *wooden mallet* called *thapi*. When plaster is to be applied in 2 or 3 coats, the first coat should be scratched while moist with cross lines like trellis work to provide a rough surface for the next coat to adhere well. Second coat is applied when the 1st coat is quite dry.

*Cornice plaster* is applied roughly to the required dimension along the line of cornice. The required shape of cornice is given by moulds passing over it and finishing by final touch.

## 3.22 Gypsum plasters

For architectural fancies, decorations and in ceiling designs, these plasters are frequently employed and in general they are suitable for all interior surfaces.

The characteristic features of tnese plasters are :

(i) Fire resistance,

(ii) Better insulation against heat and fire,

(iii) Subsequent coats can be applied without waiting for a number of days as is the case with other conventional plasters,

(iv) Once the plaster has set, it does not undergo any further expansion or contraction.

Gypsum plaster by burning gypsum rock ($CaSO_4 . 2 H_2O$) at 110°C and leaving "Calcined Gypsum", commonly known as Plaster of Paris.

Commonly used gypsum plasters are as below :

(i) *Ready mixed* : It is ready for use as calcined gypsum and fine aggregate are mixed at the mix. Only water is to be added to it. This plaster is used for both base coat as well as final coat and its insulating properties are three times that of conventional plaster.

(ii) *Neat plaster* : It requires mixing of five aggregate.

(iii) "*Wood fibred*" *plaster* : Calcined plaster mixed with not less than ·75% by weight of non-staining wood fibres. It is suitable for forming a strong base coat and is used after mixing one part of sand.

(iv) "*Acoustical plaster*" : Used for reducing sound vibrations and hence useful as sound absorption. This plaster has, however, less workability.

(v) *Keen's cement* : A high density plaster. It can receive high polish having additional resistance against cracking, to improve this defect, lime putty and fine sand are generally added to this cement.

(vi) *Gauged plaster* : In case gypsum plaster is to be applied so that the expansion is prevented during drying and also to provide initial hard surface, gypsum plaster is combined with lime putty.

### 3.23 Recommended mixed in cement mortar for different items of work and quantity of cement required per unit of work.

| Type of work | Recommended proportions of cement and sand | Unit quantity of work | Quantity of cement mortar in c. ft. to be used per unit quantity of work | Number of cement bags needed per unit quantity of work |
|---|---|---|---|---|
| Brick work in Cement Mortar,- Heavy works, such as, bridges, retaining walls, etc. | | | | |
| (a) Foundations | (a) 1 : 3 | 1 cu. m. | ·25 cm. | 2·6 |
| (b) Superstructure | (b) 1 : 5 | 1 cu. m. | ·25 cm. | 1·5 |
| Brickwork in Cement Mortar. Light structure, such as, houses, etc. | | | | |
| (a) Foundations | (a) 1 : 5 | 1 cu. m. | ·25 cm. | 1·5 |
| (b) Superstructure | (b) 1 : 8 | 1 cu. m. | ·25 cm. | 1 |
| Coursed rubble masonry in Cement Mortar. Heavy Works, such as, bridges, retaining walls etc | | | | |
| (a) Foundations | (a) 1 : 3 | 100 cu. m. | ·30 cu. m. | 3 |
| (b) Superstructure | (b) 1 : 5 | 100 cu. m. | ·30 cu. m. | 1·85 |
| Coursed rubble masonry in Cement Mortar. Light work, such as, houses. etc. | | | | |
| (a) Foundations | (a) 1 : 5 | 1 cu. m. | ·30 cu. m, | 1·85 |
| (b) Superstructure | (b) 1 : 8 | 1 cu. m. | ·30 cu. m. | 1·15 |
| Cement Plaster | | | | |
| (a) 12·5 mm Thick (on exposed walls) | (a) 1 : 4 | 10 s. m. | 1·75 cm. | ·35 |
| (b) 12·5 mm Thick (on inside walls) | (b) 1 : 6 | 10 s. m. | 1·75 cm. | ·26 |
| (c) 6·25 mm Thick (on ceilings) | (c) 1 : 3 | 10 s. m. | 1 cu. m. | ·26 |

### 3.24 Pointing

The surfaces of brickwork or stone masonry made of unsound and porous materials are generally plastered to protect them from atmospheric action. Brick masonry made of sound bricks or stone masonry made of durable stones does not require any protective coat of plaster but the joints only are finished by retouching with mortar i.e. pointed.

3.24.1 *Use.* Pointing is done on the exterior faces of walls made of sound bricks or stones for appearance, protection of joints and economy.

*Method of application.* Mortar in the joints is raked out to a depth of 2 cm. The surface to be pointed is thoroughly wetted and cleaned and then the joints are filled with required mortar for different forms of pointing. The work should be kept wet for at least 3 days after completion.

3.24.2 *Forms of Pointing.* Mainly there are three forms of pointing (Fig. 3.11).

1. When joints are filled flush to the surface with the prepared mortar then it is called *flush* pointing.

2. When joints are filled flush to the surface with the prepared mortar and joints are marked by pressing a stretched string when mortar is soft then it is called *rule pointing.*

3. When mortars in joints are slightly raised over the joints surfaces with edges properly true and parallel then it is called *tuck pointing.*

3.24.3 *Classification of Pointing.* It is divided into three classes according to the kind of mortar used : (1) *Lime pointing,* (2) *Surki pointing,* and (3) *Cement pointing.*

1. *Lime pointing*—Lime and sand, finer than those used in mortar, are mixed in equal proportion.

2. *Surki pointing*—In this case the mortar consists of 1 part of lime and 2 parts of surki.

3. *Cement pointing*—In this case the mortar consists of 1 part of cement and 2 or 3 parts of sand. It stands weather well.

### 3.25 White and colour-wash

White or colour-wash forms the finishing coat when finish is not given to the plastered surface. In India inferior walls and ceilings are

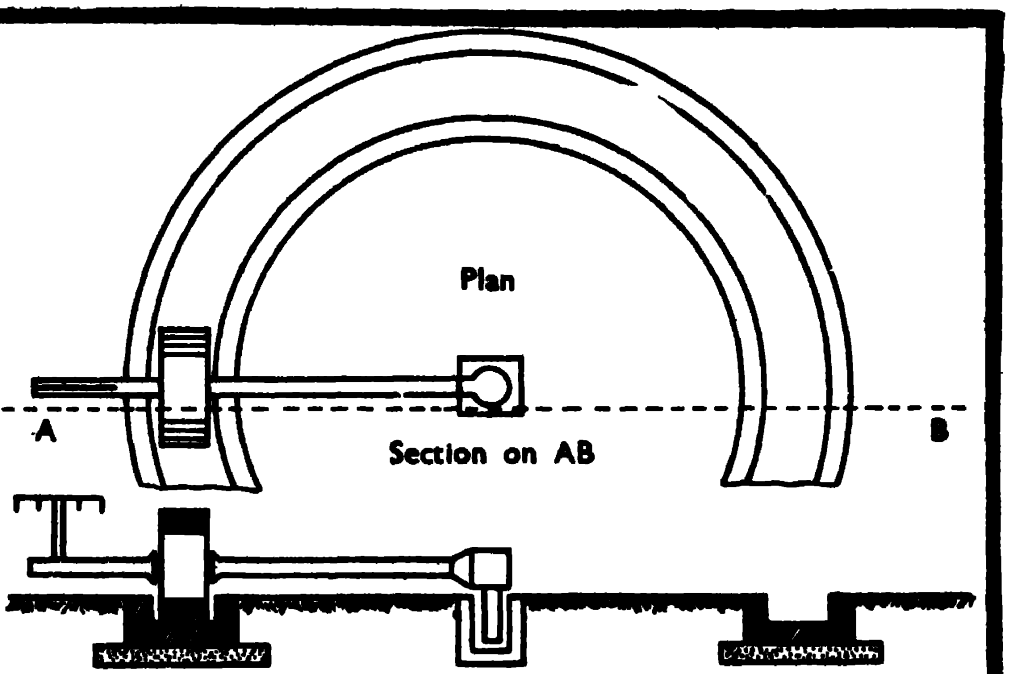


Fig. 3 9 Country mortar mill

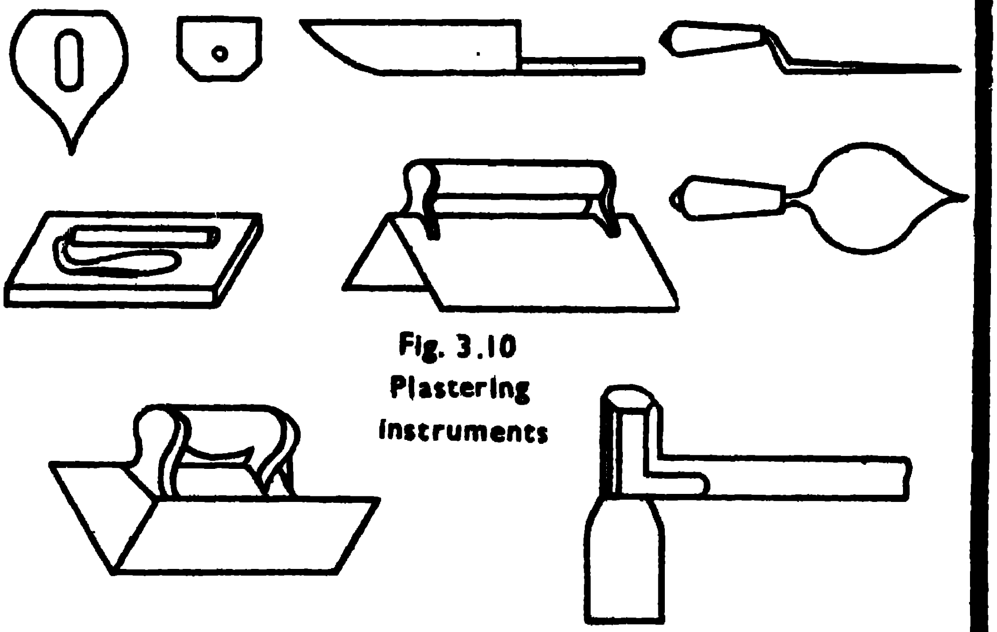


Fig. 3.10
Plastering
instruments

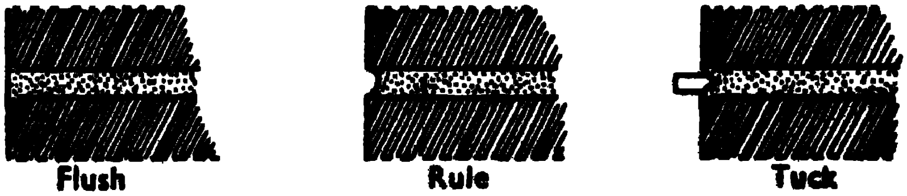


Fig. 3.11 Pointings

generally white-washed or. colour-washed instead of being pointed or papered.

*White-wash* consists of a solution of slaked stone lime or shell lime mixed with a little glue, rice water or some other adhesive substance so as to prevent the wash being rubbed off the surface easily. Freshly burnt white stone lime or shell lime is dissolved in a tub with plenty of water, thoroughly mixed and strained through a fine clean cloth to remove the coarser particles of lime. Clean gum dissolved in hot water is added to lime (50 gms of gum to ·30 $m^3$ of lime) or rice water or size is used to give good adhesion. It is to be made so thin as to drop easily from the brush which is used to apply it. White-wash is improved by adding ·5 kg of pure tallow to ·03 $m^3$ of lime. It prevents the appearance of efflorescence on the surface.

3.25.1 *Method of Application.* The new walls are to be cleaned and freed from foreign matters but in repairs, the old coat of white-wash is scraped off, thoroughly washed, and cleaned. Generally white-wash is applied in two or three coats laid alternately in vertical and horizontal directions. Each coat should be perfectly dry before the succeeding one is applied over it. Uniformity of wash depends upon the kind of brush used and the method of application.

3.25.2 *Use.* The interior plastered walls and ceilings of engineering structures are generally white-washed for appearance, cleanliness, and sanitary reasons, as lime possesses disinfecting properties, and moreover improves lighting by reflection. Some times exterior walls are also white-washed.

3.25.3 *Colour-wash.* It is a white-wash mixed with some colouring material. Wash for the day's work only should be prepared each morning and the wash should be stirred during use. In recolour-washing scrape off old colour-wash and then apply a coat of white-wash to kill the former colour and when dry the new coat of colour-wash is applied. Mixture must be stirred during use to prevent the settlement of colouring matter. It is used on plastered interior walls and ceilings for beauty, cleanliness, and sanitary reasons. The method of application is same as that of white-wash.

*Whiting* is a mixture of powdered white chalk with water and size. It is used for ceilings and inside walls. It cannot stand weather.

*Distemper* is the name for colouring matters usually earthy pigments, such as, umber, ochre, Indian red, and lamp black mixed with water and size.

*White distemper* is a mixture of whiting and size.

*Coloured distemper* is a mixture of whiting, size, and colouring pigment.

## 3.26 Concrete

Concrete is an artificial compound generally made by mixing lime surki or cement mortar with some hard material, such as, broken stone, gravel, shingle, broken brick, slag, breeze, burnt clay, etc. The mortar used in concrete is called *matrix* and the hard broken material is known as *aggregate.*

### 3.26.1 *Stages in the Making of Concrete.*

1. *Design* of concrete for strength and durability.
2. *Selection* of materials and their proportioning for requisite properties.
3. *Mixing* the ingredients of concrete and placing the same in position.
4. *Curing* of concrete for necessary reaction for strength.

Each of these stages has an influence on the properties of the finished concrete.

### 3.26.2 *Classification of Concrete.*

Ordinary concrete in generally divided into three classes and the following are some of the proportions usually used :

(1) *Lime concrete*—1 slaked lime, 2 sand and 4 aggregate.

(2) *Surki concrete*— 1 slaked lime, $1\frac{1}{2}$ sand, $\frac{1}{2}$ surki and 4 aggregate.

(3) *Composite mortar concrete*—1 cement, $\frac{1}{2}$ or 1 non-hydraulic lime, 4 or 6 sand and 10 or 12 aggregate.

(4) *Cement concrete*—1 cement, 2 or 3 sand and 4 or 6 aggregate.

The *matrix* is the lime surki or cement mortar in which hard broken material or aggregate is embeded. Strength and other qualities of concrete depend mostly upon matrix and upon the manner in which the ingredients are mixed together. The proportions of lime or cement and surki or sand should be such as will give a mortar of the required strength for the work for which it is meant. The points to be attended to are the same as for mortar already explained but as a rule the mortar for concrete should be better than that used for walls as in concrete the mortar receives less assistance. Cement used must be of a well known brand. Lime should be fresh, well slaked and free from impurities. Sand should be clean, sharp, coarse, angular and well graded. Preference is given to sand containing a mixture of coarse and fine grains. Surki should not contain underburnt particles and must pass through a sieve of I. S. Sieve No 15. Water used must be perfectly clean. Surki mortar is used with brick aggregate and lime mortar with stone aggregate.

Surki should be mixed with non-hydraulic lime to give it hydraulic property. Sand should be mixed with hydraulic lime. Non-a-days combination mortar is made by adding cement to non-hydraulic lime and sand to give early setting property to the mortar. All lime concrete should be rammed as hard and as long as possible till no water is seen on the surface. Cement concrete and *combination mortar concrete* should also be rammed hard only up to the initial setting time of cement for higher strength.

The *aggregate* is the broken stone, clean gravel of any hard material that can be procured economically near at hand e.g. broken brick, shingle, slag, etc. If weight is not essential as in the case of lintel, fire resisting material, etc. a light porous aggregate such as breeze may be used with advantage. The aggregate may be broken by hand when the quantity required is very small but when a large quantity is required, power driven stone crushers are generally used. Porous materials broken into rough angular pieces are better than those of smooth round ones because angular pieces fit into one another and are cemented together by their sides, whereas round pieces are held together by the tenacity of matrix at points where they touch one another. Further angular pieces are rougher than round ones and give better adhesion. It should be thoroughly soaked in clean water before it is mixed with the mortar for concrete otherwise it will suck moisture of the matrix and thereby greatly reduce its strength.

The *size of aggregate* differs greatly to the nature of the work. It is clear that a given voleme containing smallar sizes of particles has more total surface area of these particles than the same containing bigger size particles. So small size aggregates requiring more cement paste should be used for stronger and richer mixes. Coarse aggregate that passes through 5 cm mesh must serve for ordinary purposes, such as, foundation concrete, mass concrete, etc. The aggregate for terraced floor, roof, etc. or reinforced concrete is smaller and should pass through 2 cm mesh. Fine aggregate passes through 1 cm mesh. The void in broken stone or brick of size 5 cm is roughly 35 to 40% whereas the void in 2 cm size broken stone or brick is roughly 45 to 50%. The size of aggregate influences the void space between the materials forming it and therefore the quantity of mortar that is to be used in concrete. In all cases a mixture of different sizes or grades from minimum to maximum specified is desirable because less mortar is required in that case to fill up the voids. The maximum strength of mortar will be reached when all voids are filled. In practice the volume of matrix 10% in excess of voids is allowed. Generally 10% more sand and 15% more cement are used. The *percentage of void in aggregate* can be easily determined by filling a water-tight tank of 100 $m^3$ capacity with the aggregate well soaked in water. The amount of water that can now be added to the tank until it is full to the top is the percentage of void in the aggregate. In important works this should be determined first before mixing concrete.

| *Materials* | | *Voids in a cu. metre* |
|---|---|---|
| Broken stone of 6 cm gauge | ... | ·38 cu. m |
| ,, ,, ,, 2″ or 5 cm gauge | ... | ·4 cu. m |
| ,, ,, ,, $1\frac{1}{4}''$ or 4 cm gauge | ... | ·41 cu. m |
| Shingle ... | ... | ·35 to ·38 |
| Sand ... | ... | 6 to 9 ·22 to ·33 |

A mixture of materials of different sizes reduces the amount of voids.

*Example*—1. Design concrete if coarse aggregate and sand used have 40% and 30% voids respectively.

Sand reqd. for 1 cu. m of aggregate $= \cdot 4 + \frac{.4}{100} \times 10 = \cdot 44$ cu. m

Cement reqd. $= \cdot 44 \times \cdot 30 + \cdot 44 \times \cdot 30 \times \cdot 15 = \cdot 132 + \cdot 0198 = \cdot 152$ cu. m

$\therefore$ Cement : Sand : Aggregate $= \cdot 152 : \cdot 44 : 1 = 1 : 2{\cdot}8 : 6{\cdot}6$

2. In cement concrete the void in coarse aggregate amounted to 44% and those of fine aggregate to 30%. The size of coarse aggregate is 2·5 cm. Find the proportions of ingredients in cement concrete when 12% cement and 10% fine aggregate in excess are allowed.

Coarse aggregate $=$ 1 cu. m

Fine aggregate $= \cdot 44 \times 1{\cdot}1 = \cdot 48$ cu. m

Cement $= \cdot 48 \times \cdot 30 \times 1{\cdot}12 = \cdot 16$ cu. m

$\therefore$ Cement : Fine aggregate : Coarse aggregate : : 1 : 3 : 6

Quantity of water required is found out from slump and workability and strength is tested by cube tests.

3. Find the ingredients to make 100 parts of finished concrete if cement : sand : : 1 : 2½, voids in aggregate is 40% and the mortar in excess of voids is 10%.

Let $x$ = vol. of required aggregate.

$\therefore$ Vol. of voids $= \frac{40}{100}\,x = \frac{2}{5}\,x$

$\therefore$ $x + \frac{10}{100} \cdot \frac{2}{5}\,x = 100$ parts of concrete

$\therefore$ $x = 96{\cdot}15$ parts

Required mortar to fill voids $= \frac{40}{100} \times 96{\cdot}15 = 38{\cdot}46$ parts

Excess mortar $= \frac{10}{100} \times 38{\cdot}46 = 3{\cdot}85$ parts

$\therefore$ Total wet mortar required $= 38{\cdot}46 + 3{\cdot}85 = 42{\cdot}3$ parts and vol. of dry mortar $= \frac{5}{4} \times 42{\cdot}3 = 52{\cdot}9$ parts.

Mortar is composed of 1 part cement to 2½ parts sand.

$\therefore$ Vol. of dry cement reqd. $= \dfrac{1}{1+2\frac{1}{2}} \times 52{\cdot}9 = 15{\cdot}10$ parts

„ „ „ sand „ $= 2\frac{1}{2} \times 15{\cdot}1 = 37{\cdot}75$ „

„ „ „ aggregate „ $= 96{\cdot}15$ „

4. Find the ingredients to make 100 parts of sand cement concrete, proportion 1 : 2 : 4, having voids of aggregate 43%. Percentage of excess mortar is not known.

Let $x$ = vol. of dry cement,

$2x$ = „ „ „ sand,

and $4x$ = „ „ „ aggregate.

Volume of mortar, proportion 1 : 2 $= \frac{4}{5}$ of total volume of ingredients in mortar (average).

$\therefore$ Vol. of wet mortar $= \frac{4}{5}(x+2x) = 2{\cdot}4x$

and vol. of voids $= 4x.\frac{43}{100} = 1{\cdot}7x$.

Vol. of excess mortar $= 2{\cdot}4x - 1{\cdot}7x = {\cdot}7x$.

$\therefore$ Excess of mortar over volume of aggregate $= \dfrac{{\cdot}7x}{4x} \times 100$

$= 17{\cdot}5\%$.

$\therefore$ Vol. of dry stone including voids + vol. of mortar in excess of voids = vol. of concrete.

or $4x + {\cdot}7x = 100$ parts of concrete.

$\therefore$ $x = 21{\cdot}3$ parts (cement)

$2x = 42{\cdot}6$ „ (sand)

$4x = 85{\cdot}2$ parts (aggregate)

149 parts of dry ingredients are required for 100 parts of finished concrete.

### 3 27 Grading of Aggregate

It indicates the art of combining the various sizes of the particles composing the aggregate to produce a dense and an economical mixture using minimum cement per unit volume for a given strength. The smaller particles fill up the voids if the aggregates are graded. The particles should be angular and sharp to secure proper interlocking of the various sizes of aggregates.

*Grading* is proportioning fine and coarse aggregates to obtain densest and strongest concrete with minimum quantity of cement. The proportions may be ascertained by (i) void method, (ii) fineness modulus method, and (iii) trial method.

(i) In *Void method*, voids in fine and coarse aggregates are found out separately. 15% more cement and 10% more sand are sometimes used than percentage voids in fine and coarse aggregates respectively.

*Example*—Design concrete mix when voids in sand and coarse aggregates are 30% and 45% respectively.

Sand reqd. for 1 cu. m of coarse aggregate $= \cdot 45 + \cdot 045 = \cdot 495$ cu. m

Cement reqd. $= \cdot 495 \times \cdot 30 + \cdot 495 \times \cdot 30 \times \cdot 15 = \cdot 148 + \cdot 022 = \cdot 170$ cu. m

∴ Cement : Sand : Aggregate = 17 : 49·5 : 100 = 1 : 3 : 6 say.

(ii) To find the *fineness modulus* of a sample of aggregate the % of sample by weight retained on each of the standard seaves is determined. The total of these percentages divided by 100 gives the fineness modulus of the sample.

*Example*—Find the fine aggregate for 1 part of coarse aggregate when the mixture has a fineness modulus of 5·3. Take the fineness modulus of coarse and fine aggregate to be 6·8 and 2·8 respectively.

Fine aggregate for one part of coarse aggregate $= \frac{6\cdot 8 - 5\cdot 3}{5\cdot 3 - 2\cdot 8} = \frac{1\cdot 5}{2\cdot 5}$ $= \cdot 6$ i.e. 60%.

∴ Ratio of fine to coarse aggregate = 60 : 100.

(iii) By *trial method* a box is filled with varying weighed proportions of fine and coarse aggregates. The proportion which gives highest total weight will produce densest concrete.

### 3.28 Sieve analysis

It indicates the grading for aggregate. The series of sieves contains a set of 9 selected sieves from 4 cm to I. S. sieve No. 15. The aggregates are sieved and the percentage retained on each is recorded.

The grading limits of fine aggregates are the percentages passing or retained on I.S. test sieve No 480, 240, 120, 60, 30 and 15. It has been seen in practice that concrete whose aggregates give a smooth grading curve gives better performance. The shape and surface characteristics of the particle also influence the grading limits. Sand composed of rounded and smooth particles would give better results with coarser grading than would be allowed for sand with sharp particle and rough surface. The roughness of the grain surface increases internal friction. The grading limits for fine aggregates are as below :

| I. S. Sieve | Percent Passing | |
|---|---|---|
| | Natural or crushed ground sand | Crushed stone sand |
| No. 480 | 95 — 100 | 90 — 100 |
| No. 240 | 70 — 95 | 60 — 90 |
| No. 120 | 45 — 85 | 40 — 80 |
| No. 60 | 25 — 60 | 20 — 50 |
| No. 30 | 5 — 30 | 5 — 30 |
| No. 15 | 0 — 10 | 0 — 15 |

Generally it is easier to provide satisfactory grading of coarse aggregate than of sand. When the aggregates are screened, each sized product contains oversize and undersize material. Due to breakage during handby operation, the amount of undersized particles increases and oversized ones decreases. The I.S. specification limits the amount of oversize and undersize material in 4 cm, 2 cm and 1 cm single sized material to 15 to 20 percent respectively.

The grading limits laid down by the I.S. specification for all-in-aggregates are as below :

Grading Limits for All-in-Aggregates

| Normal size of all in-aggregate | 4 cm | 2 cm | Percent Passing | |
|---|---|---|---|---|
| | | | No. 480 Sieve | No. 15 Sieve |
| 4 cm | 95 — 100 | 43 — 70 | 25 — 45 | 0 — 6 |
| 2 cm | | 95 — 100 | 30 — 40 | 0 — 6 |

## 3.29 Proportion of ingredients

The matrix and aggregate should be in such proportions that the mortar completely fills up the voids in the aggregate. For ordinary concrete about 40 parts of mixed dry mortar to 100 parts of aggregate generally form a satisfactory proportion. The proportion is also expressed in ratios, thus 1 : 3 : 5 or 6 concrete means 1 part of cement or lime, 3 parts of sand and 5 or 6 parts of aggregate. 1 : 2 : 4 c. concrete means 1 part of cement, 2 parts of sand and 4 parts of aggregate, is the usual proportion and is known as a *standard mixture* which is used for reinforced beams, floors, arches, machine foundations, tanks, sewers, conduits, etc. 1 : 1½ : 3 c. concrete is a *rich mixture* which is used for columns and other parts of structures subjected to high stresses or requiring water-tightness. 1 : 2½ : 5 c. concrete is a *medium mixture* which is used for walls, piers, abutments, retaining walls, etc. 1 : 3 : 6 is a *lean mixture* for unimportant works. In concrete work it is generally found that the aggregate is twice the quantity of sand. Concrete made of varying sizes of aggregates will be more than that of screened ones of uniform size if proportion is same in both the cases. The proportion of water to cement should be determined as well. *Water* should be free from deleterious matter, such as, oil, acid, alkalies and vegetable matter. Sea water should not be used as it may produce efflorescence.

Concrete, mixture is expressed in three ways :

1. *Real Mix* is the ratio expressed on the basis of dry materials as obtained in the design to give the necessary strength.

2. *Field Mix* is the ratio modified to suit the field conditions, such as, moisture in the aggregates, value of slump, atmospheric condition, etc.

3. *Nominal Mix* is the ratio classified on the basis of certain nominal ratio suitable for different types of works, such as, 1 : 2 : 4, 1 : 3 : 6, etc.

### 3.30 Bulk of concrete produced

The bulk of concrete produced varies according to the nature and proportions of cement, sand and aggregate and also the method of mixing. Generally it should be a little more than the cubic content of the aggregate before mixing. The following examples show how bulk of concrete obtained varies :—

1 cu. m of broken stone or shingle

| | |
|---|---|
| ·33 ,, sand | 1 cm. of concrete |
| ·165 ,, Portland cement | 1 : 2 : 6 |
| 113·75 litres of water | |
| 1·1 cm. of broken brick 5 cm size | |
| ·37 cm. sand | 1 cm. of concrete |
| ·185 ,, Portland cement | 1 : 2 : 6 |
| 54·6 litres of water | |

When consolidated it is $\frac{9}{10}$th of the volume when first made.

### 3.31. Approximate quantities of materials required for 1 cu. m. of cement concrete

| Nominal Mix by volume. | | Cement (bags) | Sand (Dry) c.ft. | Broken stone or Brick Ballast (c.ft.) | Water (litres per bag of cement) |
|---|---|---|---|---|---|
| | 1 | | | | |
| **Cement Concrete** | | | | | |
| 1 : 4 : 8 | Mass concrete in foundations of light structures, such as, one-floored houses, etc. | 3·5 | 16 | 32 | 16·5 |
| 1 : 3 : 6 | Mass concrete in moist foundations, solid ground floors, etc. | 4·35 | 15·8 | 31·4 | 13·1 |

1

| | | | | | |
|---|---|---|---|---|---|
| 1 : 2½ : 5 | Mass concrete in machinery bases, walls below ground, etc. | 5 | 15·8 | 30·6 | 11·8 |
| 1 : 2 : 4 | Most ordinary purposes, general reinforced concrete, mass walls above ground, concrete blocks, etc. | 6·3 | 14·8 | 29·6 | 9·5 |
| 1 : 1½ : 3 | Water tight floors, tanks extra strong reinforced concrete, etc. | 8 | 14·3 | 28·6 | 7·9 |
| 1 : 1 : 2 | Long span reinforced concrete arch bridges, high load reinforced concrete columns, etc. | 11·2 | 14 | 28 | 6·3 |

NOTE :

1. In the case of wet sand the quantity given in column 4 should be increased by 25% to provide for "bulking".
2. The quantities of water given in Col. 6 are applicable to dry non-absorbent aggregates. In the case of wet sand, suitable allowance for moisture should be made; in general, reduction of 20% in the quantity of water will be adequate in most cases.

### 3.32 Mixing

Concrete can be mixed either by manual labour or by machine. The ingredients of mortar are measured out in a dry state by measuring boxes in the proportions decided upon on a clean platform of concrete or brickwork and then mixed by turning over 2 or 3 times for thorough mixing. Then the dry mixture of mortar is spread over well soaked aggregate. Necessary water is then sprinkled over the dry mixture from a water can with a rose so as to mix the whole very thoroughly. This moist mixture is again turned over two or three times for thorough and even mixing of materials. This is known as *dry method of mixing* concrete.

In large works *machine concrete-mixers* are used (See Fig. 3.12). The capacity of the mixer depends upon the size of the drum. The revolving drums has paddles inside to ensure thorough mixing by 50 to 60 rotations for each batch of mix. The drum is capable of being tilted on either side of the frame. It receives the raw materials on one side and delivers the mixed concrete on the other side. There are other concrete mixers in which loading, mixing and delivery are kept in a continuous operation. Too much water should not be used as it will wash away the lime or cement in the mixture. Generally 4·5 litre of fresh water is required for ·03 $m^3$ of concrete. If hydraulic lime be used it should be ground in a mortar mill and carefully slaked. No unslaked particles should be allowed to mix with other ingredients. Portland cement, if used, should be cooled before mixing and Roman cement must be fresh.

There is another method of mixing concrete known as *wet method of mixing* but it is inferior to *dry method.* In the wet method aggregates are mixed with wet mortar prepared before hand.

3.32 1 *Types of Mechanical Mixers.* The various types of concrete mixers used are as below :

(i) *Tilting Drum Mixers* : Normally these are of smaller capacity because of the mechanism required for tilting. However larger mixers upto 3 cu. m capacity and capable of giving 60 cu. m of finished concrete per hour exist.

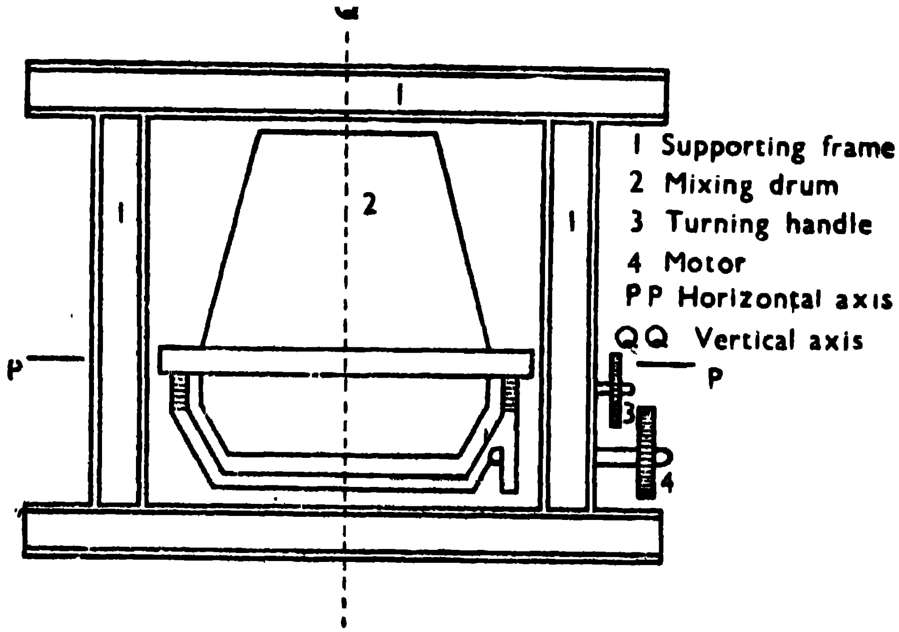


Fig. 3.12. Tilting drum mixure

(ii) *Non-tilting* : These are available in small as well as large sizes (·15 cu. m to 5 cu. m). In most cases the rotation in one direction causes mixing of the ingredients while rotation in the reverse direction causes discharge of concrete by a hopper.

(iii) *Continuous Mixers* : These mixers, once started, work continuously and the ingredients, i.e. cement coarse and fine aggregates are fed mechanically and produce 10 to 20 cu. m. of concrete per hour depending on the capacity of the mixer.

(iv) *Pan Mixer* : Used where the quantity of concrete required is comparatively small.

(v) *Truck Mixers* : When the concrete is to be carried to long distances from the central batching plant, truck mixers are employed where primarily trucks are used for mobility. The mixed concrete is transported to the work site and water separately mixed to it near the work site.

### 3.33 Laying

Concrete must be used while quite fresh. After thorough mixing the concrete is conveyed rapidly to the place where it is to be laid in wheel-barrows for small jobs or in buckets swung from a crane or in tipping trucks running on rails for large jobs and gently tipped or laid into position in horizontal layers between 15 to 30 cm thick and then consolidated.

Concrete should not be thrown from a height as the heavier particles of aggregate will tend to separate from the lighter particles of mortar and so the concrete will not be a homogeneous mass. The layers of concrete should be horizontal so as to prevent water running off and carrying some mortar with it. Layers should follow one another so that each is laid before the previous one has had time to set otherwise the surface of previous one is to be roughened by cross lines when green so as to ensure a key being formed between the layers. When circumstances require that each layer should be allowed to set separately then the surface of previous layer should be swept clean, made rough by a pick, washed and covered with a thin coat of cement especially when concrete is rammed. The surface is now fit to receive the next layer. The joints between the layers of concrete need careful attention. If proper precautions be not taken then these will be a source of weakness and layers are liable to separate.

In case of *lime or surki concrete*, lime or surki mortar is mixed dry and ground in mortar mills and then thoroughly mixed with aggregate and water. The concrete is laid in layers. Each layer of concrete is rammed with iron rammers weighing not less than 5 kg each with light quick strokes to fill up the interstices of the aggregate by mortar and to rise it to the surface When the mortar appears on the surface, the ramming is to be stopped for 24 hours to allow concrete to set a little with the mortar in the interstices. It is then wet, well rammed with heavy strokes and thoroughly consolidated before the next layer is laid. Testing of consolidation is done by digging a few holes in concrete near the edges about (10 cm) in diameter and (7·5 cm) deep. Holes are filled up with water and if water level does not go down more than 2·5 cm in 10 minutes the consolidation is considered complete. Well consolidated concrete should occupy $\frac{9}{10}$th of the original volume.

3 $m^3$ lime concrete in foundation is composed of the following dry ingredients :

| | | |
|---|---|---|
| 1. | Broken stone or broken jhama bricks— 3 to 4 cm or | 3 $m^3$ |
| 2. | Well burnt surki finely ground— | 1 „ |
| 3. | Slaked stone lime or unslaked jhooting lime ground to impalpable powder— | ·5 „ |

In terraced floors and roofs the aggregates are about 2 cm size. For 10 sq m of 12.5 cm. thick terraced concrete, ·66 cu. m of slaked lime, ·33 cu. m of surki, 1 cu. m of khoa and ·22 cm of coarse surki are required.

In case of *cement concrete*, cement and sand should be mixed dry and not ground together in mortar mill like lime or surki mortar and then thoroughly mixed with aggregate and water. It should be used at once and should not be disturbed by beating or ramming but it should be worked by hand uniformly into position by rodding and tamping by a pointed steel rod 1·5 cm diameter and 1 m long or by mechanical vibrating method for compacting. It solidifies itself as water evaporates. It should be kept wet for a few weeks.

In situations where concrete is to be placed under water, the water should be still and not flowing. In order to prevent segregation of the ingredients concrete should be placed in its final position and not allowed to fall freely.

### 3.34 Compacting cement concrete

In order to ensure a dense structure and to remove the air bubbles concrete is compacted thoroughly by means of hand tools or by mechanical vibrators.

The various hand tools used for compacting are rammers, templates for tamping and spading tod. For mass concrete work such as foundations heavy flat bottomed rammers are used until a thin film of mortar or paste appears at the surface. In case of flat surfaces which are of comparatively smaller thickness templates corresponding to the profile of the finished surface are used and tamping is done till slurry or paste appears at the top. At or near vertical faces spading is done for compacting.

The use of mechanical vibrators have revolutionised the compaction of concrete. Water cement ratio can be considerably reduced and hence for the same mix, higher strength can be achieved by the use of mechanical vibrators. Over vibrations which may cause stratification of layers or separation of its ingredients should be avoided. This judgment comes by experience but the following points may be found useful :

(i) The stage at which slurry from the concrete starts coming to the surface, is an indication of completed consolidation. At this stage air bubbles will cease coming to the surface.

(ii) The presentation of a uniform surface.

(iii) During consolidation, there is a change in the sound produced by vibrations. The stage at which this sound continues to be of the same tone indicates uniformed of concrete and hence completion of compact.

### 3.35 Joints in concrete

Two types of joints have to be provided in cement concrete work :

(i) *Construction joints* : These are joints necessitated due to temporary stoppage of the work i.e. for joining the work on two different days or due to stoppage which has caused previous concrete to set.

(ii) *Expansion and contraction joints* : Joints for allowing expansion and contraction in the concrete.

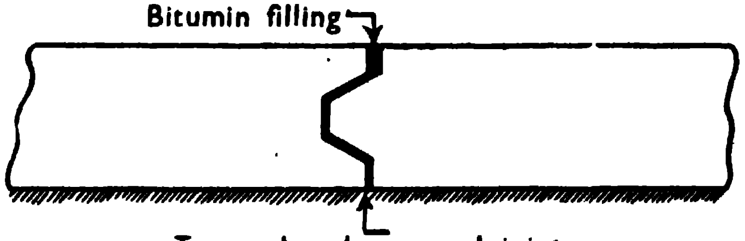


Fig. 3.13. Longitudinal joint in a concrete road

The arrangement and position of the construction joint should be planned before hand so that the joints may merge with the surroundings, or otherwise where the joints will have least adverse effect in respect of the constructional stability of the structure. The location of some of the joints is given below :

(i) *Beam* : The joint may be provided at mid span at right angles to the length of the beam i.e. at the plane of minimum shear. It may also be provided over the centre of the vertical column supporting the beam. The joint should be at right angles to the span.

(ii) *Column* : The joints may be provided at the branches or a few centimeters below the plane at which the beam or slab meets the column.

(iii) *Slab* : As in the case of beam, the slab joint may be provided at the centre of the span. The vertical joints should be so located where a pattern can be fitted or where the length of the joint is least.

When work is required to be resumed at a construction joint the hardened concrete surface should be roughened. The surface of the joint should be cleaned, washed with clean water and covered with a 1·5 cm thick mortar layer of cement and sand in the same proportion as used in the concrete.

(iv) *Expansion and contraction joints* : The purpose of these joints is to allow variations in length due to temperature changes to take place. The spacing of these joints which may be 6 mm to 38 mm wide depends upon the type of structure and type and quality of the ingredients

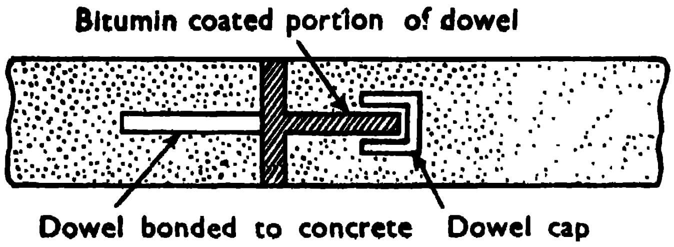


Fig. 3.14. Expansion joint in road slab

### 3.36 Finishing concrete or R.C. surface

Concrete wearing surface for floors and pavements is mostly used.

*Indian Patent Stone* is 2·5 cm thick cement concrete (1 : 2 : 4) wearing surface. It is used as floor finish by applying it over base slab already set. *Terrazzo* floor finish 2 cm thick, depending on the size of the particles required for the *mosaic* finish, composed of one part Portland cement and three parts marble chips, is applied over base slab not set as yet and rolled over. Shrinkage cracks are largely eliminated or localised by the brass or aluminium dividing strips that from the pattern of the floor. Structural cracks in the base slab will not effect the wearing coat as it is without bond with base slab.

*Mosaic* is inlaid work on plaster, brickwork or stonework or concrete. Over the lime concrete or masonry work a 5 cm thick lime concrete mortar is applied and surface is brought to a finish. Over this layer of 3 mm mortar made of 2 parts of sifted slaked lime, 1 part of powdered marble and 1 part of puzzolana is laid uniformly. After 3 hours marble pieces are hammered to form a pattern, the spaces in between being in this case filled with coloured pieces as per design. The floor is then rolled with water for a few hours. After a day the floor is rubbed with pumice stone till the surface is smooth. The surface is also rubbed with tripoli powder and powdered blue vitriol with a few drops of vinegar for extra polish whenever required.

Colouring prigments are sometimes added to the cement to obtain required shades and colour. The colour is supplied in the form of powder and this is thoroughly mixed with cement in its dry state, the coloured cement being afterwards added to the aggregates and again thoroughly mixed before the required water is added. The exact quantity will depend upon the depth of colour required but the following colour guide may be useful :

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Yellow | 88 | parts | Portland | cement, | 12 | parts | Yellow Ochre |
| Blue | 86 | ,, | ,, | ,, | 14 | ,, | Ultramarine |
| Green | 90 | ,, | ,, | ,, | 10 | ,, | Chromium oxide |
| Tile red | 86 | ,, | ,, | ,, | 14 | ,, | Ferric oxide |
| Black | 90 | ,, | ,, | ,, | 10 | ,, | Carbon black |
| Pink | 97 | ,, | ,, | ,, | 3 | ,, | Crimson lake |

*In laying concrete under water*, care should be taken to protect it during its passage down to the site of deposit under water so that water may not come in contact with it until it sets. It is usually done in one of the following ways :

(a) by moulding concrete blocks on shore and lowering them into position through water with the help of cranes and divers ;

(b) by lowering concrete in gunny bags through water into position and deposited without removing the bags but the gunny bags perish after a time leaving only the concrete on site ;

(c) by employing a bucket with doors automatically open at the bottom, freshly mixed concrete is usually deposited under water; and

(d) by pneumatic grouting of broken stone with cement mortar as semi-liquid.

[illegible]
( [illegible] )

## 5.37 Strength of concrete

15 cm concrete cubes are tested for crushing in a testing machine. The crushing strength is measured at 28 days after cube is made. The American practice is to test concrete cylinders of 15 cm diameter and 30 cm height. The cube tests give higher values usually about 25% more than those given by cylinders.

Ordinary lime, surki or cement concrete is usually allowed to take compression only. I.S. 456—1964 lays down the permissible stresses in various grades of concrete as given below :

| Grade of concrete | 7 Day Cube Stress kg/cm 28 Day Cube stress kg/cm | Permissible Stress in Compression | | Permissible Stress in Shear | Permissible stress in bond | | App. Nominal Mix. |
|---|---|---|---|---|---|---|---|
| | | Bending | Direct | | Average | Local | |
| M 100 | | 30 | 25 | 3 | 4 | 7 | 1:3:6 |
| M 150 | | 50 | 40 | 5 | 6 | 10 | 1:2:4 |
| M 200 | 135—150 | 70 | 50 | 7 | 8 | 13 | 1:1½:3 |
| M 250 | 135—200 | 85 | 60 | 8 | 9 | 15 | |
| M 300 | 170—250 | 100 | 80 | 9 | 10 | 17 | |
| M 350 | | 115 | 90 | 10 | 11 | 18 | |
| M 400 | | 130 | 100 | 11 | 12 | 19 | |

| Proportion | | | Tested when 28 days old | |
|---|---|---|---|---|
| Cement | Sand | Pabbles | Crushing Strength kg/cm$^2$ | Strength of concrete in terms of mortar |
| 1 | 2 | 0 | 150 | 100 % |
| 1 | 2 | 3 | 195 | 129 „ |
| 1 | 2 | 5 | 170 | 126 „ |
| 1 | 3 | 0 | 100 | 100 „ |
| 1 | 3 | 5 | 116 | 114 „ |

Table shows that excess of mortar is harmful to the ultimate strength of concrete. Adhesion of concrete to iron work varies from 20 to 44 kg/

*Factors affecting properties of concrete*

Strength and durability of concrete depend on the following factors :

1. Quantity of cement.
2. Size, grading and moisture contents of aggregates and presence of foreign matters
3. Water-cement ratio.
4. Proportioning of ingredients.
5. Method of measuring materials—by volume or by weight.
6. Machine mixing or hand mixing.
7. Methods adopted for placing and consolidation before initial setting.
8. Method of curing.

### 3.38 Use of ordinary concrete

Ordinary concrete is used in (1) foundation of engineering structures, (2) filling the spandrills of arches, (3) walls of houses in continuous mass or in blocks, (4) retaining walls and reservoirs, (5) stairs and steps, (6) roofing and flooring, (7) ornamental mouldings and pipes, (8) arches, lintels, etc.

### 3.39 Methods of making water-proofing concrete

(1) Aggregates are well graded and cement is proportioned to prepare a dense water-proof concrete. (2) Some substances, such as, lime, clay, puzzolan cement, etc. are uniformly mixed to make the concrete impermeable. (3) A water-proof coating on the surfaces of concrete is applied. (4) Concrete is surrounded with a bituminous casing.

### 3.40 Red cement or surki-mixed cement concrete

It is found by experiment that red cement mortar is weaker than Portland cement mortar but Portland cement mortar kept in sea water falls to zero strength in course of time while strength of red cement mortar is maintained or increases. The strength of red cement mortar in sea water is higher than in fresh water.

### 3.41 Cellur or aerated concrete

Concrete made light to float on water by introducing air bubbles throughout the mass is useful for roof slab and precast units in partitions, etc. for heat and sound insulation. It is made by adding aluminium powder to a rather wet mix of cement, sand, lime and water. The mass begins to rise due to the hydrogen bubbles evolved by the chemical action between cement and the mixture and thereby cells are formed in concrete.

### 3.42 Vibrated concrete

It is the concrete compacted by vibration. It gives best result with respect to density and strength but it is slightly costly. It requires a slightly lower value for slump than that required for hand mixing *i.e.* concrete to be compacted by vibration can be stiffer.

### 3.43 Precast concrete

When made under favourable conditions in equipped factories it is stronger and more economical than concrete *in situ*.

### 3.44 Vacuum concrete

It is the concrete in position from which air and excess water are removed with a vacuum pump. Water-cement ratio is reduced and thereby it is 20% stronger than ordinray concrete.

### 3.45 Functions of water in concrete

1. To wet aggregate surface to develop adhesion.

2. To impart workability to concrete into a plastic mixture of various ingredients.

3. To give hydration of the cementing material to set and harden during curing.

### 3.46 Water-cement ratio

It is the ratio of water used per bag (·5 quintal) of cement. The amount of water in concrete must be sufficient to ensure easy workability so that it can be conveniently packed in the formwork and around reinforcements without air-pockets. It is found that surplus water in concrete beyond the required quantity for setting of cement renders the concrete weak, makes trowelling difficult unless the operation is delayed and the final strength is inversely proportional to water cement ratio. If 22 litres of water are used for a bag of cement then water cement ratio by weight $= \frac{22}{50} = \cdot 44$. Sometimes it is expressed by volume as well.

So the strength and quality of cement depend also upon the amount of water mixed with the cement. The proportion between the amount of water and cement used in a mixture is called the water-cement ratio.

Wt. of water = 28% of the wt. cement + 4% of the wt. of total aggregate.

Gallons of water per cu. m of concrete for maximum strength $=\text{cu. m. of cement} \times \left(2{\cdot}5 + \frac{\text{cm sand} + \text{cm stone}}{50}\right)$. A well proportioned concrete mixture will result in dense concrete with smooth surfaces and free from honeycombs.

Relation between water cement ratio and strength for cube test may be plotted. It may be seen that when water cement ratio is ·3 the crushing strength is maximum.

### 3.47 Curing concrete

It means treatment of concrete with water after setting by spraying water either by hand or by pump. Strength and durability of concrete is increased by about 75, 120 and 150% when wet for $1\frac{1}{2}$, 3 and 4 weeks respectively over that which might have been expected from ordinary aging. So when concrete is set it must be properly cured.

As regards the methods of curing sand or earth may be spread thinly over the floors after the day of placing concrete when it is sufficiently hard and then water is sprinkled frequently to keep it damp.

Sometimes a slab may be ponded, or covered with an inch or so of water, held in by earth dikes at the edges. Small units may be entirely immersed in still water. When water is not available waterproof coatings are sometimes applied to concrete when it is still damp as these prevent evaporation from the surface. Vertical surfaces may be kept damp by wet gunny bags.

*Consistency of concrete* (Fig. 3.15)—It is a practice to express slump for concrete mixes to indicate the desired workability of concrete as required under conditions of casting. To maintain a uniformity of consistency throughout, samples from ready mixed heaps are taken and tested for slump as the concrete is in progress. It is denoted by slump in inches. The apparatus is a truncated cone of metal 10 cm and 20 cm diameters and 30 cm high with handles on sides. The mould is lifted vertically when filled with concrete. The depression in concrete when mould is lifted is a measure of consistency and is called slump. Normal consistency (1·00) is denoted by a slump of 2·5 cm. 10% water when added will give a slump of 10 cm and is termed 1·10 consistency but 25% of water will give a slump of 15 cm and is termed 1·25 consistency.

### 3.48 Values of slump for different concrete mixes

| Types of concrete | Slump<br>cm |
|---|---|
| 1. For precast & vibrated concrete in piles and mouldings | 2·5 |
| 2. For foundations & slabs | 5·0 |
| 3. For columns & walls | 7·5 |
| 4. ,, ,, ,, with vibration | 5·0 |
| 5. ,, ,, ,, without vibration | 12·5 |
| 6. Mass concrete | 2·5 to 5 |

### 3.49 Causes of faulty concrete

The source of concrete defects will be found in the use of dirty aggregates, too much or too little water, too little mixing, overworking of the surface, or too quick drying of the concrete.

*Mixes for different types of work*

1 : 4 : 8 —Mass concrete

1 : 3 : 6 —Mass work in foundations.
(M 100)

1 : 2 : 4 —Beams, slabs, columns, walls, foundations, roads and
(M 150) bridges generally.

1 : $1\frac{1}{2}$ : 3—Arches, tanks, hollow slabs, precast slabs, chimneys
(M 200) and marine works.

1 : 1 : 2 —Long arches, columns under high loads, etc.
(M 250)

*Shutterings*—Shutterings must be of suitable quality and adequate strength to remain perfectly rigid and true to line during placing, ramming and setting concrete. The inner face of the shutterings should be clean and treated so that a good face is imperted. All formwork must be designed and built so that it may be struck without harm to the finished concrete and must be close fitting to prevent the loss of liquid from concrete when wet.

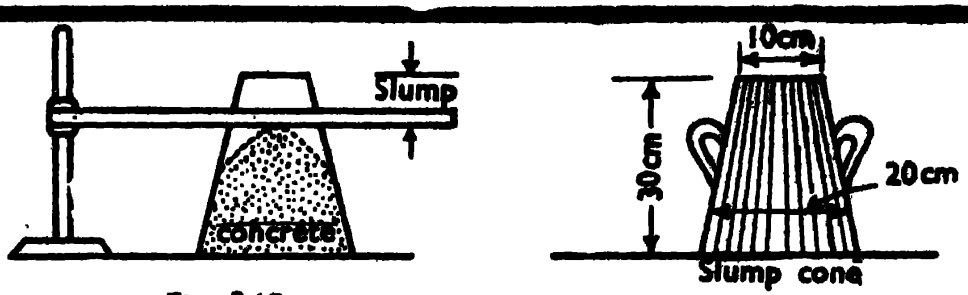


Fig. 3.15 Measurement of slump

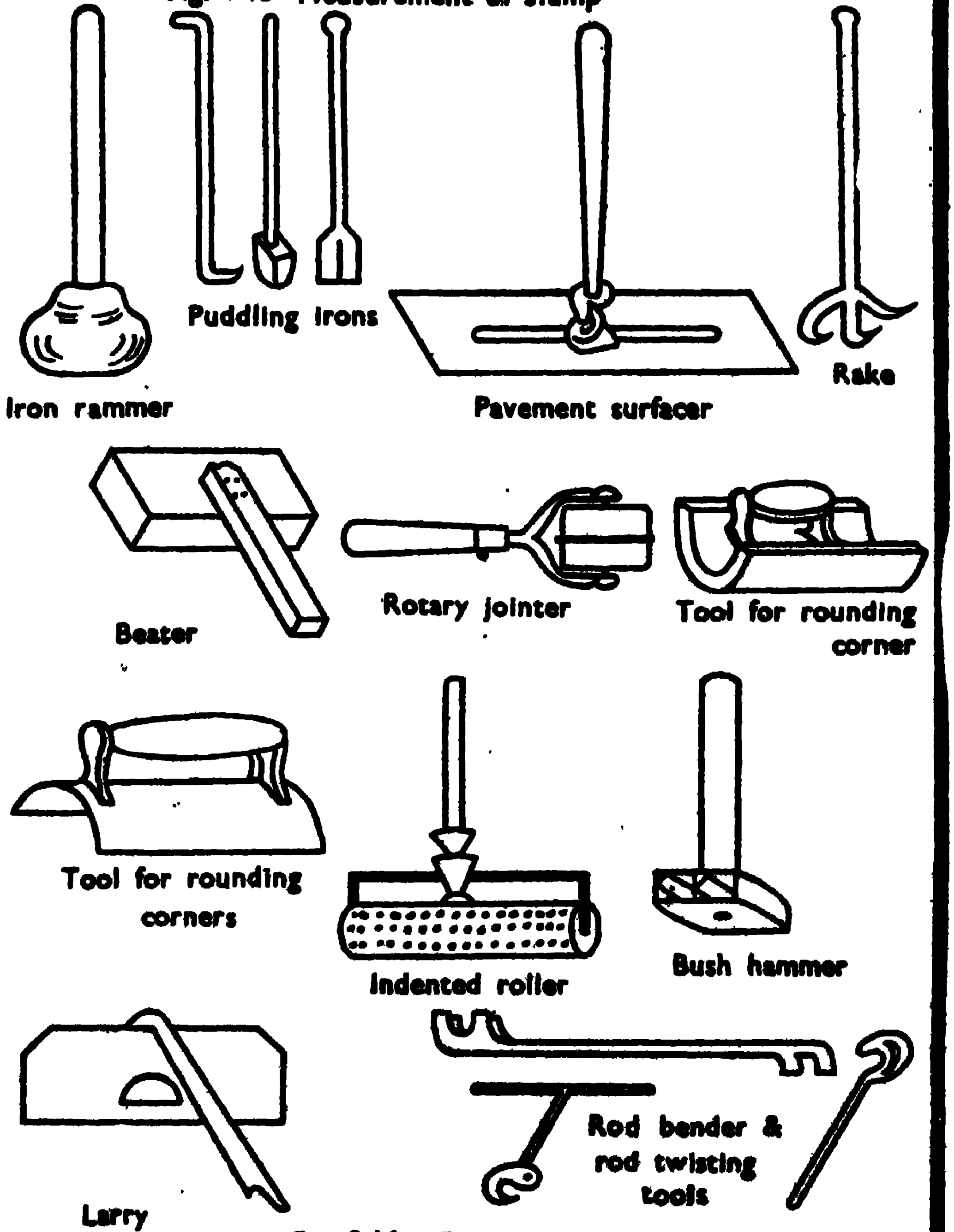


Fig. 3.16 Concrete tools

Dealwood is the best amongst Indian timbers and it is cheap, light, strong, and smooth when planed. Thickness of timber depends on the loads to be carried and the spacing of support below. Sufficient time must elapse before shutterings are stripped so that concrete will be in a condition to bear its own weight and other loads which may come over it. The initial cost of steel shutterings is high but ultimately it is economical if the work admits of its repetition.

*Time for stripping formwork* :

| Removal of Formwork | Days Cold weather | Days Normal weather |
|---|---|---|
| Walls, sides of beams and columns (unloaded) ... | 6 | 3 |
| Slabs (props left under) ... | 7 | 4 |
| Removal of slab props ... | 14 | 10 |
| Beam soffits (props left under) ... | 12 | 8 |
| Removal of beam props ... | 21 | 14 |

### 3.50 Concrete tools (Fig 3.13)

1. *Rammer*—Iron rammer weighing 10 to 15 kg is used for consolidating dry or plastic concrete.

2. *Puddling irons* have a 5 × 10 cm face for tamping concrete close to forms and between small spaced reinforcements.

3. *Wooden beater* is used for ramming concrete into moulds.

4. *Jointer*—Its projecting edge in the middle cuts deeply into the concrete for dividing into sections.

5. *Tools for rounding corners* are used for forming round corners.

6. *Plasterer's trowel* is used for rubbing smooth plaster.

7. *Pavement surfacer* is a trowel with long handle and it can be used by a man standing more conveniently and quickly.

8. *Indented roller* is used to give indentation on the surface of concrete for foothold.

9. *Impression frame* is used for making small squares on concrete and stable floors.

10. *Bush hammer* is used for dressing concrete.

11. *Rake* is used for expediting the mixing of concrete by hand adequately.

12. *Rod bender* is used for bending rods of reinforced concrete.

## 3.51 Ferro-concrete

Classification.

*Ferro-concrete* or *armoured concrete* may be divided into 3 classes :

1. *Reinforced concrete (R. C.)*
2. *Reinforced brick concrete (R.B.C.)*
3. *Reinforced brick lime concrete (R.B.L.C.)*

**3.51.1** *Reinforced Concrete (R.C.). Definition*—Reinforced concrete structure is one in which the concrete and reinforcing metal usually steel are so combined as to act together as one material and to produce a more economical material than either acting alone.

**3.51.2** *Economy and Theory of Reinforced Concrete.* Steel costs volume for volume about 50 times as much as concrete. Steel is about 30 times stronger in compression and . 00 times stronger in tension than concrete. So the cost of concrete is about $\frac{3}{5}$th and 6 times that of steel to carry a given load in compression and tension respectively. Hence in a structure a judicious combination of steel in tension and concrete in compression gives a more economical result than either material used alone.

**3.51.3** *Designs of Concrete and Steel. Composite design* is one in which either concrete or steel acts independently in resisting the stresses so that either the one or the other might carry the full load.

*Combination design* is one in which some of the loads are resisted entirely by concrete and other loads are resisted entirely by steel so that when either concrete or steel resisting one load failed then the whole structure would fail.

*Monolithic design* is one in which concrete and steel act as a single unit and produce a more economical material than either acting alone. Reinforced concrete is designed on the theory that steel does all the work on the tension side of the neutral axis and concrete on compression side.

**3.51.4** *Position of Reinforcement in Reinforced Concrete* (Fig. 3.17) —In beam lower half is in tension but in cantilever upper half is in

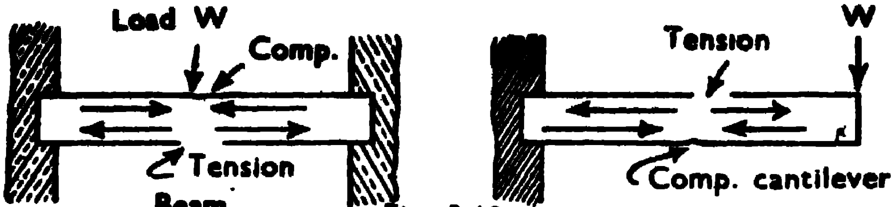


Fig. 3.18

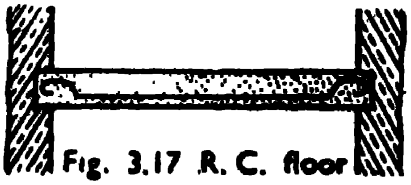


Fig. 3.17 R. C. floor

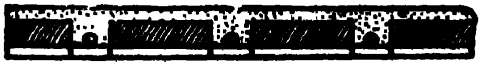


Fig. 3.21 R.B.C. floor

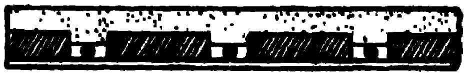


Fig. 3.22 R.B.L.C. floor

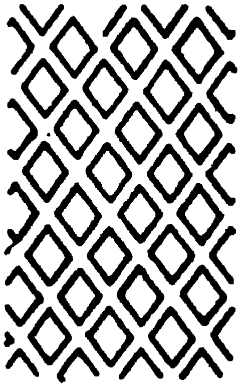
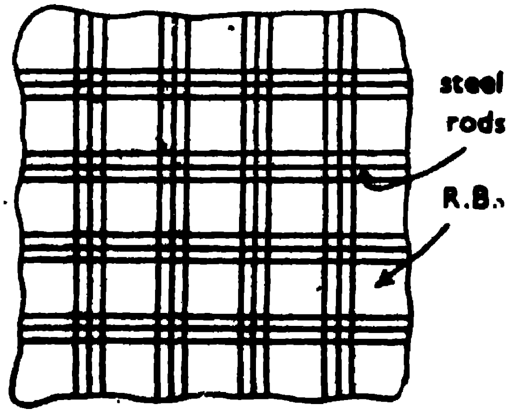


Fig. 3.19 Expanded metal



Plan

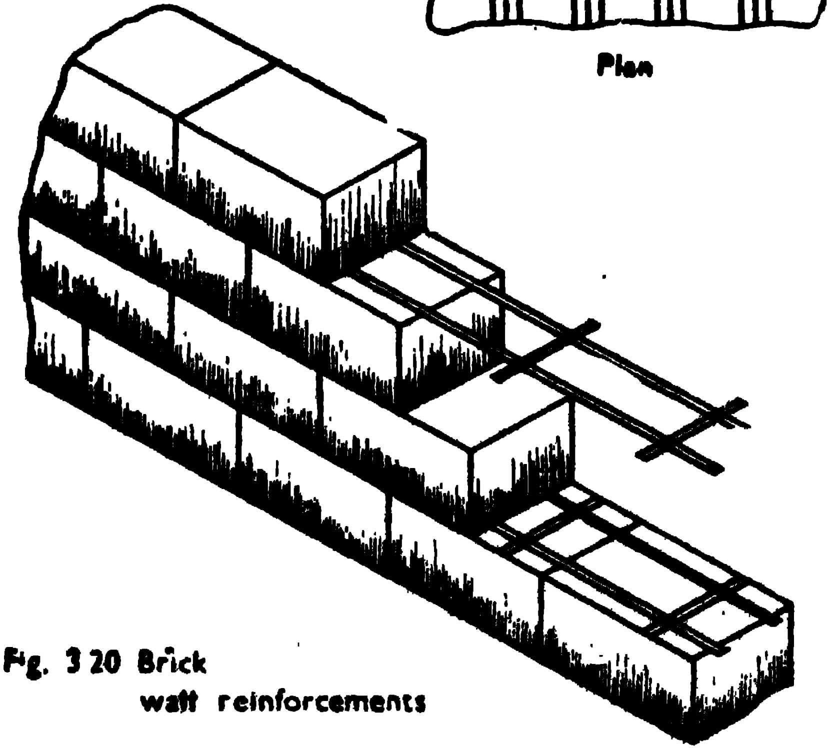


Fig. 3 20 Brick wall reinforcements

tension as shown in Fig. 3.18. In reinforced concrete mild steel rods are generally placed on tension side and cement concrete on compression side but mild steel is sometimes used on compression side as well to take compression to some extent so as to reduce the depth for convenience. In India expanded metal reinforcement (Fig. 3.19) is mostly used as it is very simple. *B. R. C. fabric* (Fig. 3.20) is an electrically cross welded steel wire mesh with wires correctly spaced and is used in reinforced brick (*R. B.*) and reinforced concrete constructions. The surface of steel embedded in concrete should be free from grease and loose scales but slight surface rust is not objectionable. The ends of steel rods must be hooked for better grip and its cover with concrete on all sides must be sufficient so that it may not be affected by atmospheric action.

3.51.5 *Reinforced Brick Concrete* (*R.B.C.*). In reinforced brick concrete (Fig. 3.21) steel rods embedded in cement concrete take tension and compression is taken by either brick or both brick and cement concrete. This is cheaper than reinforced concrete.

3.51.6 *Reinforced Brick Lime Concrete* (*R.B.L.C.*). In reinforced brick lime concrete (Fig. 3.22) steel rods embedded in cement concrete take tension and the compression is taken by brick and lime concrete. This is cheaper than both reinforced concrete and reinforced brick concrete.

3.51.7 *Dennett's Fireproof Material.* It is a concrete of broken stone or brick embedded in a mortar produced by calcining gypsum at a red heat.

3.51.8 *Use of Ferro-concrete.* It may be used for any part of engineering structures. Now-a-days even the whole engineering structure is often constructed with ferro-concrete.

3.51.9 *Pre-stressed Concrete.* It is a concrete in which a high compressive stress is artificially induced. It won't crack when it is subjected to tension as the tension is neutralised by the already induced compression. Pre-stressed concrete saves as much as 50% on concrete. The quantity of steel is also reduced as high tensile steel is used in it. Pre-stressed concrete makes economical design compared with ordinary reinforced concrete, as permissible stress in both steel and concrete being higher.

## 3.52 Some basic factors for design of R.C.C.

(i) A plain section before bending remains plain after bending.

(ii) Both steel and concrete maintain the same moduli of elasticity.

(iii) In the tensile zone all stresses are taken by steel only.

(iv) Adequate bend is developed between steel and concrete to enable transfer of stresses to take place.

3.52.1 *General Requirements of RCC Design.* The mix should be carefully designed so that max compressive strength of the concrete is available and both steel and concrete are stressed to their max permissible stresses after taking into consideration all possible loads and various criteria of failure. The design requirements may be abstracted.

1. Main reinforcement should be sufficient to resist direct tensile stresses.

2. Area of concrete should be adequate to take up compressive stresses.

3. Adequate bend should be developed between joints of the rods.

4. Adequate provision is made for shearing stresses.

3.52.2 *General Rules for Beams and Slakes.* Freely supported members (beams or slake)

1. (i) *Effective span :* Clear span + Depth of the beam or slake or the effective span, whichever is less.

(ii) *Continuous members :* The width of the intermediate supports being greater than $\frac{\text{Span}}{12}$.

(iii) *End span :* Clear span plus half the effective depth (one end free and the other continuous). In case both ends are fixed, the effective span is taken as clear distance between supports.

2. *Thickness of slake :* If the load carried is more than 750 kg/m$^2$, allow $\frac{S}{25}$ as slake thickness where $S$ is the effective span.

As per requirements of I S. Code of Practice I. S. 456—1964, the ratio of effective span to overall depth should have the following limits :

| Sl. No. | Type of slake/beam | Max value of effective span of slake/overall depth of slake |
|---|---|---|
| 1 | Sandy supported slake spaning in one direction | 30 |
| 2 | Continuous slake in one direction | 35 |
| 3 | Two way simply supported slake | 35 |
| 4 | Continuous slakes in two directions | 40 |
| 5 | Cantilever slakes | 12 |
| 6 | Simply supported beam | 20 |
| 7 | Continuous beam | 25 |
| 8 | Cantilever beam | 10 |

3.52.3 *Minimum Reinforcement in Slake.* A minimum of ·15 per cent should be provided as reinforcement for shrinkage, temperature and distribution

3.52.4 *Minimum Reinforcement in Beam.* A minimum of ·3% of the gross cross-sectional area of concrete stone be provided as tensile reinforcement.

3.52.5 *Maximum Compressive Reinforcement.* To be restricted to 4% of the gross-sectional area of the beam.

3.52.6 *Shear in Beams.* The intensity of shear should not exceed 4 times safe permissible shear stress for the concrete.

The spacing of stirrups shall not exceed the lever arm and the diameter of the rods shall not be less than 5 mm.

A minimum reinforcement as stirrups should be provided throughout the length of the beam at a spacing less than the lever arm irrespective of the safe shear.

If steel beam theory is adopted for the compressive reinforcement, the stirrup spacing should not exceed 8 times the diameter of the compression bar.

3.52.7 *Bond.* The bond stress should not exceed the permissible bond.

The bar should extend ·23 cm or 12 times the diameter of the bar, whichever is more to allow transfer of stress by bond. The extended portion may be bent to form a hook.

3.52.8 *Curtailment of Bars.* With the decrease in bending moment, reinforcement may be proportionately curtailed. However, at least 25% of the main reinforcement should be carried over the support upto the length required from bond consideration.

### 3.53 Efflorescence on walls

The surfaces of walls are sometimes covered with an efflorescence of an unsightly character. It is formed by the action of damp air forming saltpetre on the surface.

3.53.1 *Appearance.* It is usually white in colour and crystalline in structure ; crystals look like a thin coating of snow.

3.53.2 *Composition.* These efflorescence crystals usually consist of sulphate of magnesia, sulphate of lime, carbonate or nitrate of soda, chlorides of soda and potash, or carbonate of potash.

3.53.3 *Causes.* Efflorescence is sometimes attributed to bricks or stones of the masonry structure but sometimes to the mortar. Dampness is favourable to its formation. Freezing cold stops efflorescence.

3.53.4 *Disadvantages.* (1) It presents a disagreeable appearance. (2) It causes damp patches on the surface of the structure. (3) It will eat through paint, plaster and mortar and will gradually disintegrate fragments of the materials of the structure.

3.53.5 *Precautions.* In this case prevention is better than any attempt at cure and so it is better to avoid all materials mentioned above as likely to give rise to efflorescence. As regards bricks, clay containing pyrites or much magnesia should not be used for brick-earth but special bricks may be burnt with coke or wood. As regards mortar limestone containing magnesia to a great extent should not be used for making lime.

3.53.6 *Remedies.* The following remedies may be tried if it does occur in case of ashlar work : (1) The surface is covered with a wash of powdered stone, clean sand and water, which is then cleared off. Pores are filled up and efflorescence is stopped temporarily. (2) Apply paint or 2 coats of paraffin oil over the surface before the commencement of the efflorescence.

The mortar before use may be treated to prevent it from causing efflorescence by mixing 4·5 kg of fatty matter to 45 kg of lime. Potash salts are rendered harmless by adding hydrofluosilicic acid.

Efflorescence may be entirely stopped by applying Sylvester's washes, which consist in using two washes for applying on walls—one is of soap and water, and the other is of alum and water.

## EXERCISE III

### A. M. I. E (I) Examination Questions

1. Distinguish between (i) cement concrete, (ii) reinforced cement concrete, and (iii) prestressed concrete. What are the specific functions of each? What are the ingredients that go to make up cement concrete? (Nov. 1961)

2. Describe the process of manufacture of cement in a modern factory. What precautions would you take in storing cement both at the factory and at the work-site. (Nov. 1961)

3. (a) Explain, with sketches, the process of manufacture of lime. (b) Mention some of its uses in engineering works. (c) Compare and contrast the advantages and disadvantages of using lime and cement in engineering works. (May 1960)

4. (a) What are the standard specifications of Portland cement and how are they tested? (b) What ingredients are required in preparing mortar and concrete? Explain the purpose of each ingredient. (Nov. 1960)

5. Write briefly on: (a) artificial stones, (b) terrazzo, (c) P. C. C. and R. C. C., (d) importance of sand in different mortars. (Nov. 1959)

6. (a) Describe briefly with sketches the process of manufacture of good Portland cement. (b) What is meant by curing of concrete and what are the methods used? (Nov. 1958)

7. Write explanatory notes on: (i) test for fineness of grinding of cement, (ii) continuous type of concrete mixer, (iii) importance of fineness modulus in the design of concrete mix, (iv) terrazzo finish. (May 1958)

8. (a) Differentiate between ordinary and hydraulic limes and mortars. (b) Give the composition of surki mortar and the special conditions under which it can be used. (Nov. 1957)

9. Explain how Portland cement is manufactured. What is meant by rapid hardening cement? What are the conditions under which this is used? (Nov. 1957)

10. Write short notes on: (i) a continuous type of lime kiln, (ii) vacuum concrete, (iii) air-entrained concrete. (May 1957)

11. State the various tests of ordinary Portland cement and give their recommended values. Describe how the tensile strength is tested. Explain the terms: (i) hydraulicity of cementing material, (ii) water-cement ratio. (May 1957)

12. Explain the principles of making (i) mortars (ii) concrete, pointing out the influence of size of fine and coarse aggregates, and water-cement ratio on the proportioning and strength of mortars and concrete. (Nov. 1956)

13. (a) What are the various ingredients of Portland cement? Discuss the functions played by each in imparting specific properties to it. (b) Write notes on (i) calcination and hydration, (ii) proportioning, (iii) clinkering (iv) grinding. (Nov. 1956)

14. Write short notes on: (a) rapid hardening cement, (b) hydraulicity of lime, (c) distemper, (d) mortars. (May 1956)

15. What is plaster and why is it used? Enumerate the different kinds of plaster commonly used, mentioning their composition and typical applications. (May 1956)

16. What is Portland cement? What are its important properties and how are they tested? Give an outline method of its manufacture. (May 1956)

17. Give a general scheme for the evaluation of the quality of Portland cement and indicate the principles underlying the different methods of proportioning concrete. What precautions are necessary for laying sound concrete? (Nov. 1955)

18. What is Portland cement? Give an outline of a method of its manufacture, and state why gypsum is added to it. Compare the setting of cement with that of lime mortar. (Nov. 1955)

19. How would you evaluate the quality of building sand? (May 1955)

20. Describe briefly a method of burning limestone for lime manufacture. Compare the setting of lime with that of Portland cement and indicate how their qualities are affected on storage. How would you evaluate the quality of Portland cement? (Nov. 1954)

21. (a) Outline in brief the manufacture of cement, giving a line diagram showing the various stages in the manufacture.

(b) Give field test for lime. (May 1954)

22. (a) Describe, giving sketches, the process of manufacture of lime.

(b) Give the classifications and properties of different types of lime.

(c) Describe the relative merits of lime mortar concrete and cement mortar concrete. (Nov. 1953)

23. (a) Explain the following: (i) bulking of sand, (ii) fineness modulus, (iii) water cement ratio.

(b) Describe the relative quantities of dry materials to be used of coarse aggregate having 45% voids and sand having 30% voids, the mortar to be of 1 of cement to 2 of sand and to be 20% in excess of voids of the large aggregate. (May 1953)

24. When and by whom was Portland cement first invented and manufactured? Write down the British standard specifications for tensile strength, setting, and fineness of Portland cement now in practice. What is the difference between 'rapid hardening cement' and 'slow setting cement', and for what particular requirements are these used? (Nov. 1952)

25. Why is it necessary to cure concrete, and what are the methods used? (May 1952)

26. What do you understand by Portland cement? How is it manufactured commercially? (Nov. 1951)

27. Explain the terms: (a) quick lime, (b) slaked lime, (c) fat lime, (d) hydraulic lime, (e) artificial hydraulic lime, (f) poor lime. (May, 1951)

28. (a) Describe, with sketches, the process of lime burning in this country.

(b) To what class of lime the following belong: stone lime, shell lime, and kankar lime. What would you prefer for foundation, superstructure, and roof concrete ?

(c) What do you understand by setting of lime mortar? Explain why it sets even in thick joints inside brickwork. (Nov. 1950)

29. What tests (both field and laboratory) would you apply to ensure if the cement supplied at the site of concrete work are up to the specification ?
(Apr. 1950, Nov. 1951, Nov. 1952)

30. (a) What are the different kinds of lime available for use on works? Mention the uses of each variety. Indicate the chemical reactions taking place during the slaking and setting of lime.

(b) What are the important precautions necessary in storing cement ?

(c) Give proportions of cement concrete to be adopted in respect of (i) reinforced concrete beams and slabs, (ii) reinforced concrete water tanks, (iii) reinforced concrete piles. (Apr. 1950)

31. Describe the importance of the following RCC work :

(i) W. C. ratio, (ii) Bulking of sand, (iii) Slump test, (iv) Curing.
(May 1960)

32. Before starting work of cement concrete construction on a large building what condition and tests would you consider essential in prescribing a cemet mix and how were you put them into effect. (Nov. 1963)

33. Describe briefly how lime is prepared and explain the difference between quick lime, hydraulic lime and fat line. (May 1963)

34. (a) Describe briefly a method of burning lime stone for manufacture of lime.

(b) Explain the difference between quick lime, hydraulic lime and fat lime.
(May 1966)

## Other Examination Questions

35. Describe with sketches the process of lime burning in India. What limes are used for (a) foundation in damp soil, (b) superstructure, and (c) roofing of a building. If they differ give reasons for your selection.

36. Draw a section of a perpetual lime kiln, and explain the method of burning, stating the amount of coal required to burn 1,000 maunds of limestone and the amount of quick lime produced therefrom.

Give the quantities of materials for (1) 100 c.ft. of masonry in burnt bricks and lime mortar in superstructure, (2) 100 c.ft. of exterior sand plaster ½" thick, and (3) 100 c.ft. of brick-in-lime concrete in foundation.

37. Explain the object of (a) grinding mortar in mills, (b) adding sand to cement or lime for plaster of mortar work, (c) soaking bricks in water before use, and (d) adding surki to lime for making mortar.

38. In lime mortar sand is sometimes only mixed and surki is sometimes only mixed with the lime. On other occasions a mixture of surki and sand is used. State the advantages and disadvantages of each type of mortar.

What quantity of different materials will be required for 100 c.ft. rammed lime concrete in foundation ? How is foundation concrete prepared and used ? How would you test its setting ? State a practical method of ascertaining the quantity of mortar to be used in concrete.

39. Why is sand used with cement ? What kind of sand do you consider the best to be mixed with cement ? Write short notes on different kinds of sand ?

40. What is mortar ? What are its constituents and what proportions are they used ? How many bricks will be required in the construction of a wall 50 long, 1' 8" thick and 4' high ? What amount of ingredients (i) by weight (ii) by volume, will be required in the preparation of mortar for this wall ?

41. What is concrete ? How is it prepared and used ? Give three specifications of concrete and state for what purpose you would use each. Give the quantities of materials measured dry to make a hundred cubic feet of foundation concrete. Sketch any apparatus, you may know for mixing the ingredients of mortar. What precautions are to be taken in the preparation and used of mortar.

42. What do you understand by voids ? How can they be measured ? A reinforced concrete roof measures 25'×15'. The aggregate for it has 35 per cent voids. Find in maunds and c.ft. the different quantities of materials that will be required for its concrete, if its thickness be 4 inches and it is made up of 1 : 3 (cement : sand) mortar.

43. What do you mean by reinforced concrete ? What are its constituents ? Give instances of the use of reinforced concrete in modern engineering works.

44. What is Portland cement ? For what purposes it is used ? Do you know where Portland cement is manufactured in India ?

45. A wall 50' long 1' 3" thick and 8' high is to be built of bricks (P.W.D. size) in mortar consisting 1 part sand, 1 part surki and 1 part lime. Find out the quantities of materials you will indent for them all.

46. Give the summary of Indian Standard Specification for Portland cement. What is the weight of a bag of cement and what is its volume ?

47. What are the functions of sand, surki and lime in a mortar ?

48. What are the different sources of obtaining sand ? Which of them is best ? Give the characteristics of good sand.

49. What precautions will you take in storing Portland cement, and why ? What is meant by properly cured concrete ?

50. A small bungalow with verandah and flat roof is to be constructed in your State. Write briefly about materials you will specify for the following giving

reasons for your choise : (a) foundation concrete, (b) superstructure masonry, (c) lintel, (d) roof. (e) floor, and (f) verandah pillar.

## Engineering Services (I) Examination Questions

51. What is reinforced concrete ? How is it prepared and used ? Write down the British Standard Specifications for tensile strength setting and fineness of Portland cement in practice. What do you understand by water-cement ratio ? (1961)

52. Explain the purpose of (a) grinding mortar in mills (b) adding sand to cement or lime for plaster or mortar work, (c) soaking bricks in water before use, and (d) adding surki to lime for making mortar. (1961)

53. What is Portland cement ? Describe the process of manufacturing Portland cement. Illustrate your answer with a flow diagram showing the different units of the manufacturing plant. What is the weight of a bag of cement and what is its volume ? (1960)

54. (a) Describe with sketches the manufacture of lime. State the chemical changes involved in the burning, slaking and setting of lime. Indicate the influence upon the setting properties of lime, of the impurities contained in the limestone and describe briefly a method of obtaining hydraulicity with a lime made from a pure limestone. (b) Indicate the difference with British Standard test for initial and final setting time of Portland cement. (1958)

# Chapter 4

## TIMBER

### 4 1 Definition

*Timber* (derived from Saxon word 'timbrian' meaning to build) is wood of sufficient size suitable for engineering purposes and is applied to trees measuring not less than 0·6 m in girth. When the wood forms part of living tree, it is called *standing timber*; when felled, it is called *rough timber*; when bark removed and hewned roughly, it is called *log*; and when sawn into various market sizes, such as, planks, battens, beams, posts, etc. it is called *converted timber.*

### 4.2 Growth of trees

Trees as divided into two classes : the *phanerogams* and *cryptogams*, the flowering and non-flowering trees. It is the wood of the former class that is used for the arts. Again the phanerogams have two divisions : *exogens* outward grower with distinct consecutive rings e.g. teak, babul, etc. and *endogens*, inward grower e.g. palm, bamboo, etc. Timbers from exogenous trees only are used for engineering works as those from endogenous trees are very flexible and slender.

Trees are also classified as (a) *deciduous* or those which shed their leaves in winter, and (b) *evergreen.* Timber is derived almost from deciduous trees.

In spring season the tree sucks food from the soil in the form of sap which rises through the roots for the growth of its branches and leaves. The sap loses moisture, absorbs carbon from air in presence of sunlight and becomes denser. In the autumn season, the thickened sap descends and is collected below bark in a layer which when hardened adds a layer of wood to the outside of the tree every year.

## 4.3 Structure of a timber tree

The structure of a timber tree is shown in Fig. 4.1. On examining the cross-section of the trunk of a timber tree, four parts are distinctly noticeable viz. : (1) *Pith, heart* or *medulla* ; (2) *Medullary sheath, medullary rays* or *transverse septa*; (3) *Annual ring* (*duramen* or *heart wood* and *alburnum* or *sap wood*) ; and (4) *Bark* or *cortex.*

1. *Pitch, heart* or *medulla* consists entirely of cellular tissue and is the innermost part or core of the stem.

2. *Medullary sheath* consists of vascular tissue which encloses the pith. *Medullary rays* or *transverse septa* are vertical layers of cellular tissue and spider like radial lines from pith to the bark binding the annual rings to one another. When radial lines are large and distinct these are called *silver grain, felt* or *flower.* These are sometimes broken and in some trees not easily visible.

3. *Annual rings* consist of cellular tissue and woody fibre arranged in distinct concentric circles or rings round the pith generally one in every year. These are formed due to the deposition of sap below bark. In temperate climate the outer part of the annual ring is darker in colour and denser than the inner part but it is homogeneous in tropical climate. So the number of annual rings indicates the age of a tree in a tropical climate.

*Heat wood* or *duramen* consists of the inner annual rings round the pith. It is compact, strong, durable and darker in colour.

*Sap wood* or *alburnum* consists of the outer annual rings. It is liable to decay and lighter in colour. The thin layer below bark not converted to sap wood as yet is called the *cambium layer.*

4. *Bark* or *cortex* consists of cells of wood fibre and is the outermost cover or skin of the stem.

## 4.4 Time for felling

The best time for felling trees is mid-summer or mid-winter when the sap is minimum in quantity as it is then at rest but the timber is liable to decay if felled in spring or autumn when the trees contain the maximum quantity of sap due to its vigorous movement.

There are too much sap wood in young trees, so they should be felled when full growth is attained but if full grown trees are allowed to stand long, the valuable heart wood is spoiled as then the timber is brittle and lacks elasticity. Good timber trees generally arrive a maturity between 50 and 100 years.

The following points should be taken into consideration in connection with felling of trees :

1. All trees to be felled should be inspected and serially numbere before felling.
2. The direction of felling should be determined beforehand before starting the cut.
3. The butt end should be rounded to facilitate the removal of fitness and ensure direction of felling. In the case of hard wood good quality timber trees, this is done two to three years earlier in which case the process is termed as "Girdling'. This prevents further forming of the sap and evaporated of some of the moisture content of the tree.

## 4.5 Sap wood improved in quality

The sap wood of trees is improved in strength and durability by stripping of the bark of the entire trunk without wounding sap wood in the preceding spring season. It may also be improved in quality if the tree is girdled before felling *i.e.* if an axe cut is made completely through sap wood and leaving it to stand until it is dead. First method is better than the second one.

*Different grains of timber*

Timber is *coarse grained* if its annual rings are wide but *fine grained* if they are narrow. It is *straight grained* when fibres are parallel to the axis of the trunk or branches. It is *twisted* or *cross grained* when fibres are twisted around the tree or when fibres of different layers cross one another.

## 4.6 Defects in timber

Several natural defects occur in all kinds of timber caused by the nature of the soil upon which the tree grew and also by the changes in nature to which it was subjected while growing. These defects should be avoided or removed as far as possible during conversion for use. The following are the most common defects in timber :

1. *Heartshakes* (Fig. 4.2) are splits or clefts occurring in the centre of the tree and running from pith towards sap wood in the

direction of medullary rays. The splits are hardly visible in some cases but in others quite prominent. These are caused by the shrinkage of the interior parts due to age and indicate that decay has begun at the centre. A heartshake straight across the trunk is not a serious defect as in the conversion it divides the trunk into two substantial bulks but it causes much waste in conversion when crossing at right angles.

2. *Starshakes* (Fig. 4.3) are those in which several splits radiate either from the centre of timber or from the bark running in the planes of medullarv rays. These may arise mostly from severe frost and fierce heat of the sun. They are mostly confined to sap wood.

3. *Cupshakes* or *ringshakes* (Fig. 4.4) are curved splits which separate the whole or part of one annual ring from another. These are mostly due to unequal growth. They do no great harm when they occupy only a portion of the ring.

4. *Radialshakes* (Fig. 4.5) are similar to starshakes, and occur in felled timber when exposed to sun in seasoning. Radial-shakes are identified from true starshakes due to the erratic course of the former. The splits are irregular, fine and numerous. Many splits appear to start a few inches within the bark, run a short distance towards the centre, then follow the course of an annual ring and lastly go towards the centre radially.

5. *Rind Galls* (Fig. 4.6) are typical curved swellings caused generally by the growth of layers over the wounds left after branches have been imperfectly lopped off.

6. *Upsets* or *rupture* (Fig. 4.7) are portions of timber where fibres have been injured by crushing. These are due to unskilful felling and also the result of violent wind.

7. *Twisted fibres* or *wandering hearts* (Fig. 4.8) are caused by the action of a prevalent wind twisting the young tree constantly in one direction. Timber thus injured is not fit for squaring but it may be used for posts or poles.

8. *Foxiness* is a red or yellow tinge due to the commencement of decay

9. *Wind cracks* (Fig. 4.9) are shakes or splits on the sides of a balk of timber due to the shrinkage of the exterior surface exposed to atmospheric influences.

10. *Knots* (Fig. 4.10) are the roots of small branches of the tree. They are live or dead. They break the continuity of fibres. These are

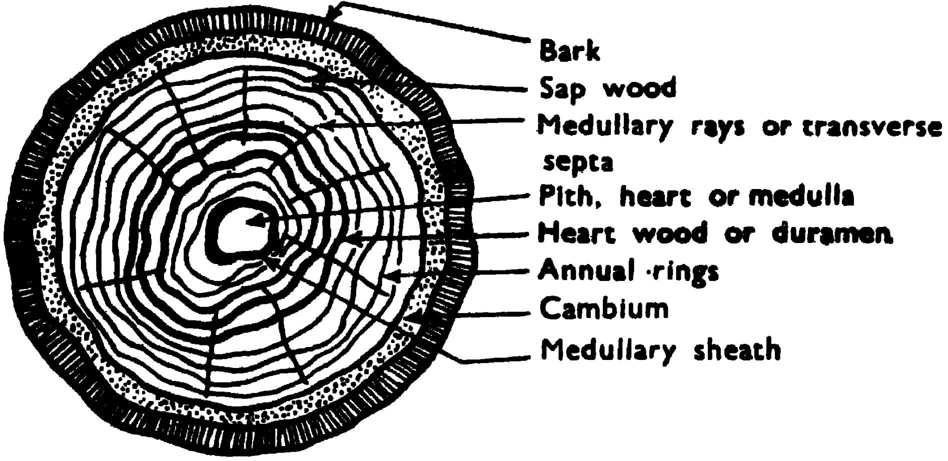


Fig. 4.1 Cross section of a tree stem

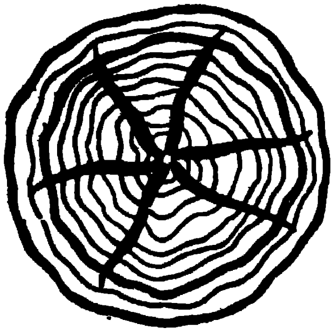


Fig. 4.2 Heartshakes

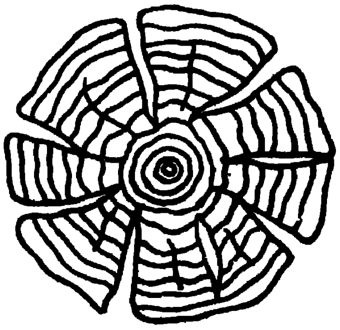


Fig. 4.3 Starshakes

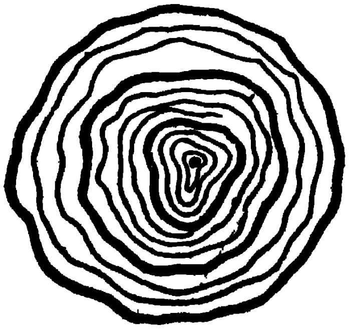


Fig. 4.4 Cupshakes

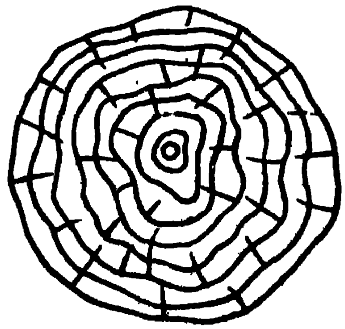


Fig. 4.5 Radialshakes

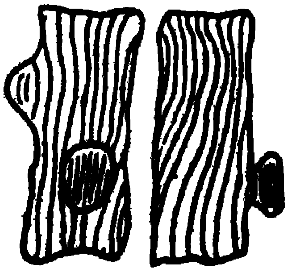


Fig. 4.6 Rind-Galls

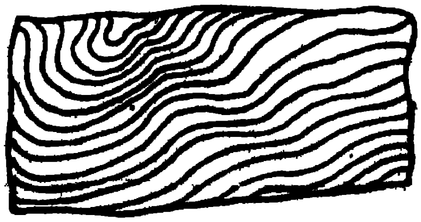
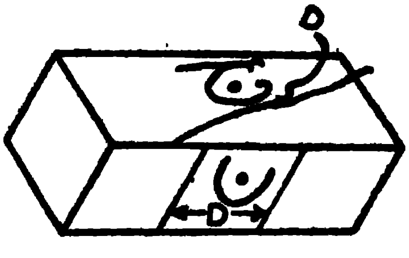


Fig. 4.7 Upsets

not very harmful when small, hard and round and used in members other than tie bars and beams. Timbers containing large dead (loose) knots or many smaller ones should be rejected as they are poorer in appearance and strength.

I.S. 3629—1966 gives the permissible sizes of knots in grade I structure timber as below :

| *Width of face in mm* | *Size of knot D in mm max* | |
|---|---|---|
| | *Narrow face and ¼ of the width of wide face close to top and bottom edge* | *Central half of width of wide face* |
| 75 | 19 | 19 |
| 100 | 25 | 25 |
| 150 | 38 | 38 |
| 200 | 44 | 50 |
| 250 | 50 | 57 |
| 300 | 54 | 75 |
| 350 | 57 | 81 |
| 400 | 63 | 87 |
| 450 | 66 | 93 |
| 500 | 69 | 100 |
| 550 | 72 | 103 |
| 600 | 75 | 106 |



11. *Honeycombing* (Fig. 4.11) is set up when the interior of the timber dries out after case hardening.

12. *End splits* (Fig. 4.12) are checks extending through to two faces.

13. *Deadwood* is deficient in strength and weight and is the result of trees being felled after maturity.

14. *Druxiness* is an early decay which appears as whitish spots. It is due to fungi giving access and setting decay.

## 4.7 Characteristics of good timber

The quality of timber depends upon (a) the treatment the tree has received, (b) the time and age of felling, and (c) the nature of the soil in which it has grown. The followings are some principal features which are characteristics of good, strong and durable timber :

1. Narrow annular rings due to slow growth ; wide annular rings generally indicate weak and soft timber.
2. Firm addition of fibres, hard and compact medullary rays.
3. Uniform in texture ; darkness in colour ; straight in fibres.
4. Heavy weight.
5. Sweet smell, hard and shining appearance at a freshly cut surface ; bad smell or dull chalky appearance is a sign of bad timber.
6. Sonorous when struck ; a dull heavy sound indicates decay within.
7. Show no wooliness at a freshly cut surface nor clog the teeth of saw with loose fibres.
8. Free from sap wood, large or dead knots, flaws, shakes or blemishes of any kind.

## 4.8 Preparation of timber tree seasoning by squaring

Logs of timber are liable to split if left exposed to change of atmospheric condition. So a timber when felled should be lopped, barked and hewn square by sawing in order to give free access of air into pores of timber and to hasten its drying. Logs may be sawn up for scantlings of required size prior to removal and seasoning if it is not very green one.

## 4.9 Seasoning of timber

A freshly felled tree always contains sap both in sap wood and heart wood. Seasoning of timber consists in getting rid of all the sap and moisture out of it so that it will not decay by the fermentation of the sap, or warp or bend owing to uneven expansion or contraction of the moist timber with the rise or fall of temperature. The advantages of using seasoned timber are that it works easily under saw and plane and retains its size and shape even after it leaves the hands of carpenters and joiners. The strength of green timber is about doubled by proper seasoning. Timber becomes less in bulk and weight due to seasoning. Timber fit for carpentry is seasoned when it looses $\frac{1}{5}$th of its weight and fit for joiners when about $\frac{1}{3}$rd of its weight has been lost after felling. Seasoning is *natural* or *artificial. Air seasoning* is natural seasoning but *water seasoning, seasoning by boiling or steaming, hot air seasoning, McNeills' process, smoke drying, charring* and *scorching* are artificial seasoning. Natural method is very slow but artificial one is a quicker method.

1. *Natural* or *air seasoning* (Fig. 4.13) is carried out by stacking timber with spaces between them so that there can be free circulation of air and at the same time protecting it from the sun and rain. It should be kept clear of the ground by a foot or two supported on damp proof bearers. The timber should be turned frequently if possible. Irregular drying will cause splitting. This is the best but slow method of seasoning. It takes 2 to 4 years before the timber is suitable for carpenters' or joiners' work.

2. *Water seasoning* consists in totally immersing timber in water perfectly in a running stream soon after felling for 3 to 4 weeks. The sap in timber is then washed away by water. It is then taken out and carefully dried with free access of air. Partial immersion in water is very harmful. It is a quick process and renders timber less liable to warp and crack, but weakens the timber. Salt water makes timber harder and durable but timber will have a tendency to absorb moisture.

3. *Seasoning by boiling in water* is a very quick method and takes only few hours. It causes less shrinkage but reduces strength and elasticity of timber and moreover it is an expensive process.

4. *Seasoning by steaming* has more or less same effect as boiling but it prevents dry rot.

5. *Hot air seasoning* or *desiccation* consists in stacking timber in chambers and then exposing it for about 3 days to a current of hot air which dries up the sap. It makes timber brittle and bleaches highly coloured timber.

This process of seasoning by passing hot air is also known as kiln seasoning. Two types of kilns namely compartment kiln and progressive or continuous kilns are used for this purpose. In the compartment type kiln, kiln load of timber is stacked and humid air is introduced into the chamber. Temperature is then gradually raised and humidity decreased till the optimum moisture content required for the seasoned timber is achieved. During the process of seasoning specimen pieces

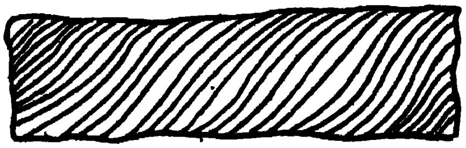


Fig. 4.8 Twisted fibres or wandering hearts

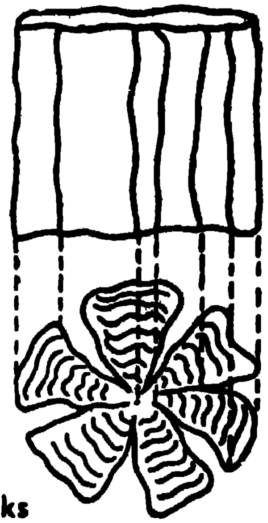


Fig. 4.9 Windcracks

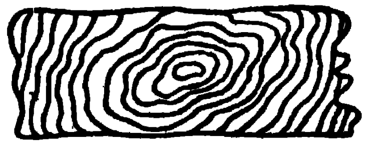


Fig. 4.10 Knot

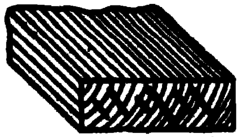


Fig. 4.11 Honeycombing

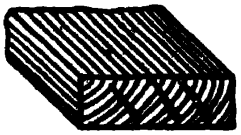


Fig. 4.12 End-splits

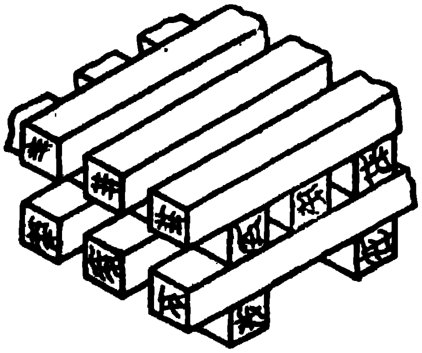


Fig. 4.13 Air seasoning

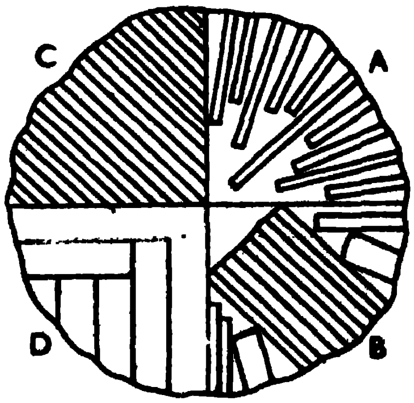


Fig. 4.14

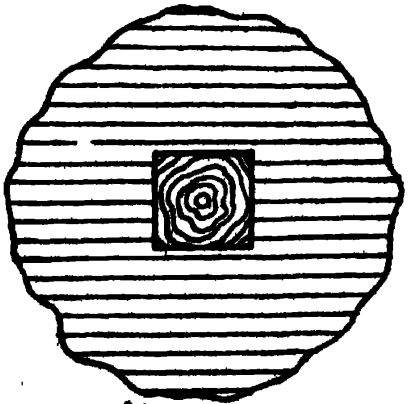


Fig. 4.15

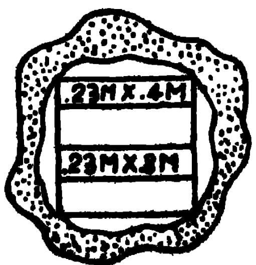


Fig. 4.16

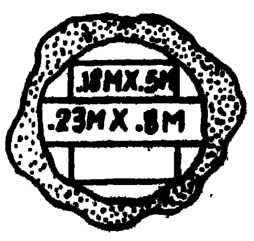


Fig. 4.17

Fig. 4.14 – 4.17 Conversion of timber

are taken out to determine the condition of seasoning. In the continuous process type of kiln seasoning timber in the wagon is changed from one end of the chamber, gets dried up and season as it advances and seasoned sections are unloaded from the other end. The hot air inlet is from the discharge end to ensure gradual heating of the timber section.

6. *McNeill's process* is the best method of artificial seasoning as it has no injurious effect upon the appearance and strength of timber. It consists in exposing the timber to a moderate heat in a moist chamber charged with various gases produced by the combustion of fuel. Timber is rendered harder and denser. It is costly but it prevents dry rot entirely.

7. *Smoke-drying* consists in drying timber over a fire of straw or twig. Heat is applied gradually to prevent splitting. It makes timber harder, more durable and proof against worm attacks. This process is generally adopted for bending planks in boat building.

8. *Charring* or *scorching* is best for piles and others that are to stand in water or in ground. This process produces dry rot in green timber. Scorching is also used for boat building.

### 4.10 Second seasoning

Some timbers require a second seasoning after they have been worked e.g. doors and other articles of joinery are left for some time after being made before they are wedged up and finished.

### 4.11 Decay or diseases of timber

Sound and well seasoned timber in a well ventilated position or entirely immersed in water will last for many years. Moisture, imperfect seasoning, alternation of dry and wet state, vegetable growth and attacks of insects are the principal causes of decay in timber. Heat and moisture combined are most injurious. So timber should be kept dry, well ventilated, clear of earth, and away from damp mortar and wall. Two forms of decays most known are *dry rot* and *wet rot*.

*Dry rot* is a disease in timber caused by want of ventilation. Such situation promotes the growth of fungus which eats into the fibres of timber and reduces them to dry powder, thus rendering it very brittle. The growth of fungi accelerates the progress of dry rot but the origin of the disease is due to the decomposition of sap in the timber first and then this decomposition supplies food for the growth of fungi. Timber seasoned or unseasoned may be infected with these germs. Charring,

tarring, painting or varnishing unseasoned timber also causes dry rot. In timber dry rot generally occurs in warm cellars, under unventilated wooden floors, basements, ends of timber built into walls without protection or ventilation, etc.

### 4.12 Detection of dry rot

A log of timber may be full of dry rot inside though not perceptible from outside. It can be easily detected by tapping or scratching at one end and placing the ear at the other end of the log. The log is sound if the tapping is distinctly heard otherwise it is a sign of internal decay. A log apparently sound from outward look may be full of dry rot inside, which can be detected by the appearance of dry powder extracted by an auger from the timber or by its smell.

### 4.13 Prevention of dry rot

Well seasoned timber free from sap should be used to prevent dry rot as sap wood is attacked first. Provision must be made for free access of fresh air for good circulation. The disease is infectious and so the best remedy for timber attacked with dry rot is to cut away the affected parts and then to paint the remainder with a solution of copper sulphate. The best way of checking dry rot is to sweep fungus off the timber and make provision for the thorough ventilation of free air round it.

*Wet rot* is the decomposition of timber caused by damp and moisture. It is generally induced by alternate wet and dry conditions. While wet it is decomposed and scales off when dries. Standing tree or timber exposed to rain is subjected to the attack of wet rot.

### 4.14 Prevention of wet rot

Timber for exterior work or work underground should first be seasoned to remove sap and then protected from moisture by painting or tarring.

### 4.15 Difference between dry rot and wet rot

Dry rot can take place only when the timber is dead and occurs in confined places but wet rot can take place when timber is dead or alive and occurs in places where gases produced can escape easily.

### 4 16 Preservation of timber

Timber has to be preserved from moisture, dry rot or internal decay and from the attacks of insects. Timber should be well ventilated when fixed in position, thoroughly seasoned and painted before fixing.

Paint on seasoned timber preserves it from moisture and extends its life indefinitely if renewed periodically but timber should be thoroughly seasoned before the paint is applied as otherwise protective coat will shut up the sap by closing outside pores and thereby induce decay. Many processes have been adopted for protecting timber from dry rot and insects by impregnating it with chemical substances. *Tarring*, *charring*, *painting* and *creosoting* are the usual methods of preservation.

### 4.17 Advantages of the use of preservative

1. Timber which has been treated with preservatives has longer life which may be three to four times the life of untreated one.

2. The increased life span means less replacement or maintenance cost of the structure as a result of which the timber which otherwise would have been used for replacement can be used for other structures.

### 4.18 Requirements of preservative

1. Timber is a comparatively cheap material hence the preservative should not increase the cost that is, it should be cheap.

2. It should be simple in application so that a non-skilled or semi-skilled person can do it.

3. It should be readily available in large quantities.

4. It should not corrode building materials which come in contact with timber.

5. It should be poisonous to fungi and insects.

6. It should not be inflammable if not fire resistance.

7. It should be stable.

8. It should be penetrating type.

9. It should be odourless and colourless.

*Tarring* consists of coating the timber with coal tar while hot. Door and window frames built into walls and rough works are generally tarred.

*Charring* is carried out on the end of the post that is embedded in the ground. It is best done over wood fire. The end of the post is quenched with water when it is charred to the depth of $\frac{3}{4}$th inch.

*Painting* consists in applying 3 coats of oil paint and is renewed periodically. It improves the appearance as well.

*Creosoting* (Bethel's method) consists in placing timber in an air tight impregnating chamber from which air is pumped out. Creosote oil under a pressure varying from 7 to 10 kg/cm² and at a temperature of about 48°C is then forced in so long the timber will absorb oil generally for 1 to 2½ hours. It doubles the life of timber properly treated and is quite satisfactory. It preserves timber effectively both from rot and white ants. It is usually adopted for railway sleepers, piles and poles.

*Solignum* protects the timber from the attack of white ants. It is coloured with pigments to make the timber attractive appearance.

*Impregnating with metallic salts*—The result of the impregnation with various metallic salts has not been quite satisfactory.

*Ascu* is a preservative used at the Forest Research Institute, Dehra Dun. It consists of 1 part (by weight) of hydrated Arsenic pentoxide, 3 parts of blue vitriol and 4 parts of potassium dichromate. 6 parts of powder are dissolved in 100 parts of water and sprayed on timber to make it immune from the attack of white ants.

### 4.19 Protection against worms and insects

Creosoting, tarring, etc. preserves timber against such attacks. Creosoting is a satisfactory preservative against attacks of white ants but it is used for outside work only on account of its bad smell. Seasoned teak requires no protection as it is unaffected by white ants.

Arsenic prevents to some extent the attacks of these white ants and so is sometimes used in paints. Margary's process of injecting sulphate of copper solution (·45 kg sulphate of copper to 18 lits of water) is a good protective from the attacks of white ants. Kerosene is effective but its smell remains. Creosoting is the best preservative against white ants but it is adopted for outdoor work for its smell.

### 4.20 Preservation of timber from fire

Sir Abel's process consists in first painting over clean and smooth surface of timber with a dilute solution of silicate of soda, then with cream like slaked fat lime and lastly by strong solution of the silicate. This process is more satisfactory than Burnet's process in which timber is soaked in a solution of zinc chloride and water.

### 4.21 Classification of timber

Timber used in engineering works is divided into two classes :

1. *Soft wood, pine wood,* or *coniferous wood*—annular rings distinct; resinous wood; straight fibre and resists tension or pull;

lateral adhesion of fibres weak enabling easy split. Pine, fir and cedar belong to this class and are useful in making masts, spars, etc.

2. *Hard wood, leaf wood,* or *non-coniferous wood*—annular rings are more or less distinct ; non-resinous wood ; equally strong along and across fibres ; flexible, strong and tough wood capable of bearing tension, compression or shear. Teak, mahogany, oak and sal belong to this class and are most suitable for building works.

3. I.S. 3629—1966 gives the following classification :

*Class I* : Natural durable heart wood timber having average life of 120 months or over.

*Class II* : Natural durable heart wood timber having average life of 60 months or over but less than 120 months.

*Class III* : Timber having average life less than 60 months.

4. From the consideration of strength of the timber, it may be classified as average, good and very good depending upon the modulus of elasticity '$E_t$' and modulus of rupture $\rho_t$ as given below :

*Average :* '$E_t$' between 66000 kg/cm$^2$ and 98000 kg/cm$^2$ and $\rho_t$ between 85 and 120 kg/cm$^2$.

*Good :* '$E_t$' between 98000 and 126000 kg/cm$^2$ and $\rho_t$ between 120 kg/cm$^2$ and 180 kg/cm$^2$.

*Very good :* '$E_t$' greater than 126 kg/cm$^2$ and $\rho_t$ greater than 180 kg/cm$^2$.

5. Yet another classification may be made taking into consideration the seasoning property of the timbers. From this consideration it may be divided as below :

1. Non-refractory wood which can be satisfactorily seasoned in the open without developing any defects. Timbers like Salai and Semul come under this category.
2. Moderately refractory timbers which can be seasoned with suitable precautions against rapid drying. Teak, Sheesham Tun and Sisoo come under this class.
3. Eminent refractory timbers which require special precautions during seasoning. Heavy structural timber like Sal fall under this category.

## 4.22 Conversion of timber

The cutting up of logs to form planks, battens, etc. of the required sizes by saw is called *conversion*. Power machines are employed in several stages when working on a large scale. During conversion due allowance should be made for shrinkage, squaring and planing usually $\frac{1}{8}''$ to $\frac{1}{4}''$ or 3 to 6 mm. Beams should be sawn out of timber so that it may not contain pith and this is done by first sawing the timber through pith into two halves. Strong pieces are obtained from timber when saw cuts are tangential to annular rings and more or less parallel to the direction of medullary rays as shrinkage takes place parallel to the direction of the annular rings.

Timber may generally be sawn in one of the following ways :

1. Ordinary sawing

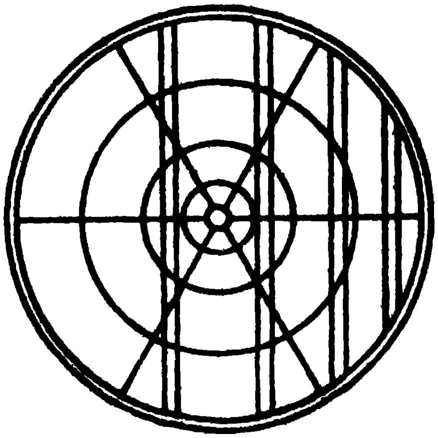


Fig. 4.18 Ordinary sawing

Parallel skien of timber are cut by moving the log backward and forward along the saw mill. Though the sawing is convenient yet because of different sections appearing in a particular plank, unequal shrinkage resulting in warping occurs.

### 2. Tangential sawing

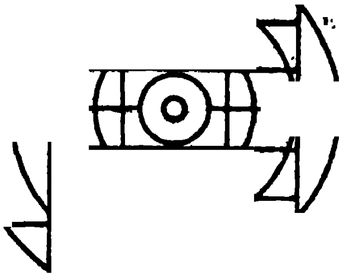


Fig. 4.19. Tangential sawing.

The sawing is done at right angles to the medullary rays and tangential to the annual rings. Due to the cutting of the medullary rays, the sections cut become weaker.

### 3. Radial sawing

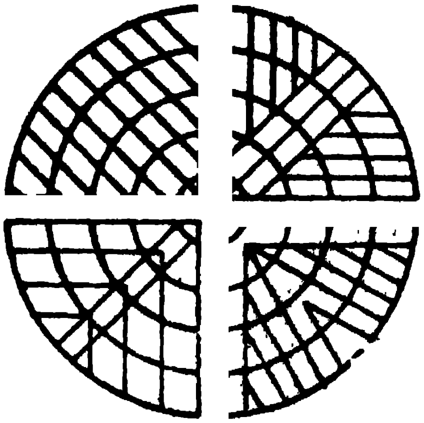


Fig. 4.20. Radial sawing

The sawing is done parallel to the medullary rays and perpendicular to the annular rings. The cut section shrinks at a uniform rate and the warping is therefore less. The wood therefore can be used for high quality timber works. There is however considerable quantity of wastage and its takes longer time for conversion.

4. Quarter sawing

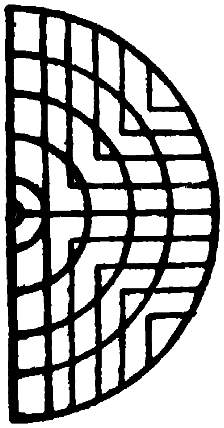


Fig. 4 71. Quarter sawing

The log is first divided into form quadrants and each quadrant may be sawn in any of the standard matter.

### 4.23 Conversion of hard timber such as oak

The log is first cut into 4 parts. In Fig. 4.14, at A the method is best—no waste and much used for cabinet work and other ornamental works, at B it is next best and at C it is inferior to others but that at D is the most economical where thick stuff is required. Method in Fig 4.15 is a practical one for cutting oak logs in order to get wide boards where all boards are parallel to the same diameter.

### 4.24 Conversion of soft timber such as fir (Fig. 4.16)

It shows an arrangement usually adopted at present but the method in Fig. 4.17 is also sometimes adopted.

### 4.25 Loss of conversion

The data given below are a guide to the probable losses in the conversion of timber from log to the finished article : (a) Round logs to thick planks—40% ; (b) Square logs to thick planks—30 ; (c) Round logs to scantling—50% ; (d) Square logs to scantling—40%.

*Wastage during sawing*—In the conversion of timber by sawing the wastage is well over 40% of the log weight. The refuse from the saw mills may be classified as follows :

| | |
|---|---|
| Saw dust | 12% |
| Trimmings | 18 ,, |
| Bark, moisture, etc. | 10 ,, |
| Total | 40% |

### 4.26 Stronger beams and good floor boards

Timber beams having annual rings parallel to their depths are stronger than those which have annual rings parallel to their widths. In Fig. 4.22 the beam cut out from A will be stronger than that cut out from B.

In making floor boards, care should be taken so that hearts may not appear on the surface of the finished board otherwise the central portions will become loose and will form a rough and unpleasant floor as in Fig. 4.23.

### 4.27 Strongest and stiffest rectangular timber beams

(Graphical method)

For *strongest beam* divide the diameter AB at C and D of the log into three equal parts as shown in Fig. 4.24. Draw perpendiculars on AB at C and D up to the circumference at E and F. Join AE, EB, BF and AF. Then AEBF is the section of the strongest beam that may be cut out.

For *stiffest beam* divide the diameter AB of the log into four equal parts as shown in Fig. 4.25 and make necessary constructions as before, then AEBF is the section of the stiffest beam that may be cut out.

### 4.28 Moisture content percentage

$$= \frac{\text{Weight of moisture in sample}}{\text{Oven dry weight of sample}} \times 100.$$

If the initial weight of sample be 51·56 grams and that after oven dry be 40·31 grams then the moisture content of the sample

$$= \frac{51{\cdot}56 - 40{\cdot}31}{40{\cdot}31} \times 100 = 27{\cdot}9\%.$$

### 4.29 Alteration in forms of a badly seasoned timber

Effect of shrinkage after few years on five planks formed by 4 saw cuts on unseasoned log is shown in Fig. 4.26. The central plank after due seasoning and contracting takes the form as shown where it retains its original thickness at the middle due to the resistance of medullary rays but gradually reduces towards the edges for want of support and the breadth is same as before shrinking; the planks at each side of the centre still retain original thickness at the centre but reduces a little at each edge, are curved and so slightly reduced in breadth; the two outermost planks are found to have lost practically none of their thickness at the centre and at edges, are curved and much reduced in breadth. Fig. 4.27 indicates the shape of a squared quarter cut out from a tree when green. Due to the effect of shrinkage after a year or two *abcd* will take the shape *a'b c'd*. Planks shruked to curved forms when used to form a flat board are sometimes sawn down at the middle and fixed together with alternate pieces being reversed as shown in Fig. 4.28.

### 4.30 Market forms of timber

The principal forms into which timber is converted are as follows :

1. A *log* is a trunk of a tree having felled and branches lopped off.
2. A *balk* or *squared timber* is obtained by roughly squaring the log.
3. A *plank* is a parallel sided piece of timber roughly 2 cm. to 4 cm. wide, 2·5 cm. to 10 cm. thick and 2·5 metre to 6 metre long.
4. A *deal* is a plank 5 cm. to 10 cm. thick and less than 22·5 cm. wide.
5. A *batten* is a plank 4 cm. to 5 cm. thick and less than 23 cm. wide.
6. A *board* is a plank less than 5 cm thick and over 15 cm. wide.
7. *Scantlings* are miscellaneous cut stuffs.
8. *Ends* are short pieces of scantlings, deals, battens, etc. cut off in the conversion of standard lengths.
9. *Poles* or *spars* are long sound logs free from knots and greatest diameter not exceeding 20 cm.
10. *Inch masts* are poles of diameter more than ·6 metre.
11. *Hand masts* are poles of diameter from 5 cm. to 20 cm.
12. *Rough timber* is log roughly hewn to an octagonal section.

### 4.31 Measurement of timber

Timber is bought and sold in the market by cubic metre. If the size of log varies in different parts then length, breadth and depth of these parts must be measured separately. Timber cannot be less than ·6 m in girth and so in measuring standing timber the length or height is to be taken up to where the girth is ·6 m. In measuring rough log take one-fourth of the middle girth as the side of the square that may

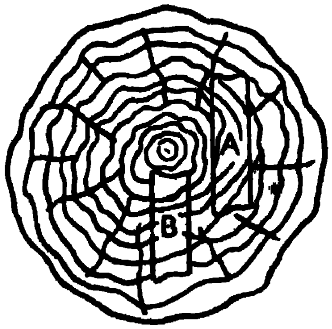


Fig. 4.22

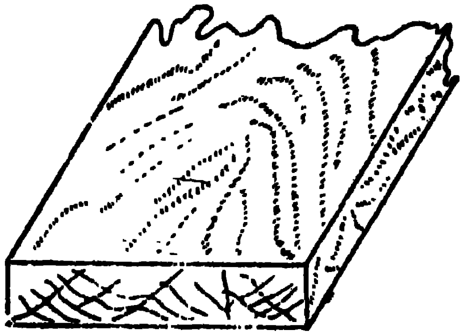


Fig. 4 23

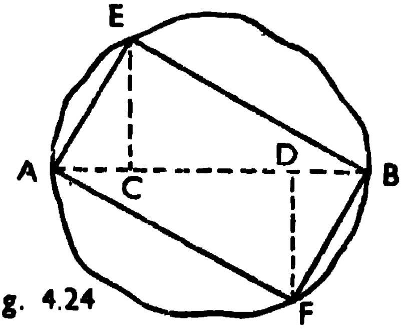


Fig. 4.24

Strongest rectangular beam

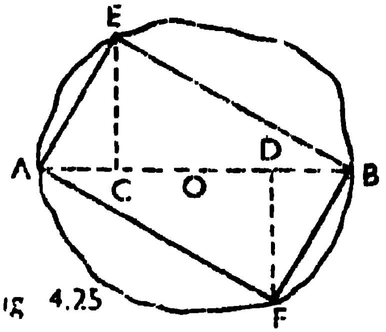


Fig 4.25

Stiffest rectangular beam

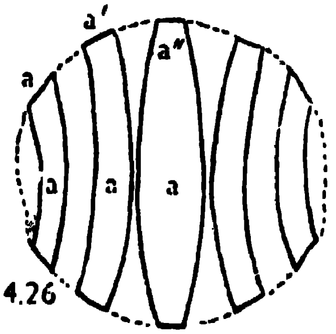


Fig. 4.26

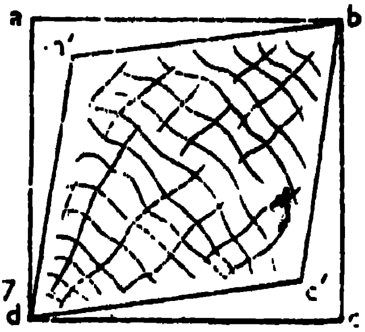


Fig. 4.27

Effect of shrinkage

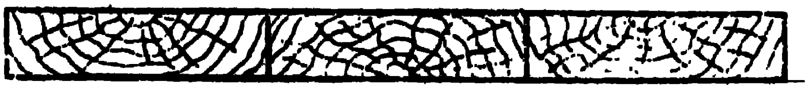


Fig. 4.28 Flat board

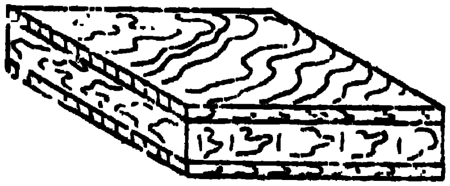


Fig. 4.29 3=Plys

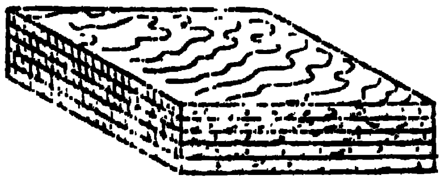


Fig. 4.30 5=Plys

Plywoods

be cut out of log. If the bark is on, deduct $\frac{1}{12}$th of the girth before dividing it by 4. Contents of timber = area of square × length

$$= \left(\frac{\text{middle girth}}{4}\right)^2 \times \text{length.}$$

The cubic contents of round or squared* logs can also be determined approximately by measuring their girths at the two ends and the middle. If $c_1$ and $c_2$ are the quarters of the end girths and $c$ the quarter of the middle girth, then the volume of a log L unit long $= \frac{1}{9} L (c_1 + c_2 + c)^2$.

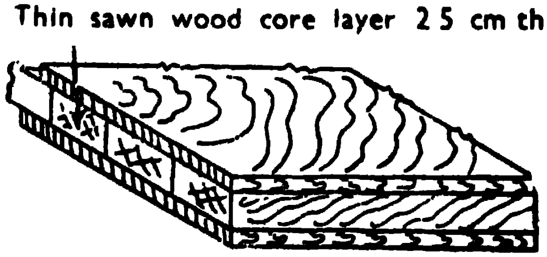
### 4.32 Wooden blocks

These are used for road surfacing in front of schools and hospitals to mitigate noice. These are now laid over a concrete foundation. Now-a-days creosoted soft woods have replaced the hard woods. Rectangular blocks are laid across the carriageway with the grains vertical. A surface dressing of bitumen and chippings is usually applied to prevent wear and to provide a non-skid surface.

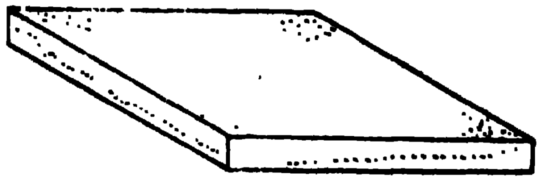
### 4.33 Plywoods (Fig. 4.29 & 4.30)

*Veneers* (thin sheets of wood) are produced by rotary cutters where a knife blade is firmly held against a log which is rotated. The sheets as turned out are cut into sizes, dried and graded as suitable for cores or faces. Teak, Sissoo and Toon are some of the Indian timbers capable of producing high grade figured veneers of approved merit. *Laminboards* and *battenboards* are made from veneers with an inner core of veneer or sawn timber. In the lamin board, the crossbands between the two face veneers consist of multi-veneers cut edge-ways and glued and pressed into a sheet 1 cm. to 5 cm. thick but in the battenboard the core consists if sawn wood 2 cm. to 2·5 cm. thick. *Fibreboards* are rigid boards 3 mm. to 12 mm. thick made by pressing hard a heated mass of wood. Some imported patented fibre boards are known by their trade names as follows : *Celotex* (1·25 cm), *Hardboard* (3 mm), *Masonite* (3 mm), *Treetex* (3 mm, 12 mm) and *Nordex* (3 mm). *Jollyboard* (3 mm, 6 mm) is an Indian product which is an excellent substitute for Masonite and others. *Lightboard* made from wood wool cemented into slabs under pressure are (1) imported *Heraklith* (15 cm to 10 cm) and (2) local *thermofriz* and *thermocoustic*. These are used as insultation boards against transmission of heat and sound. *Plywood* or *pressed wood* is made by gluing three or more veneers having the direction of grain running at right angles to each other in alternate layers. Joints are made glued, semi-dry glued or wet glued. The wet glued or semi-dry glued methods of production are less costly but are not so reliable as the dry glued method. The adhesive-coated sheets are assembled and pressed together by hand cold press or hydraulic hot press depending on the type of adhesive used and the type of board to be produced. It is advantageous to have the sheets dried on removal from the press. The finishing process is carried out by scrapers and sanders to give smooth even faces. The advantages and disadvantages are (a) decorative appearance due to figures on the top veneers, (b) elastic material and not liable to split due to changes in the atmosphere, (c) very easy to work and available in large sizes, (d) suitable for concrete shuttering, and (e) increased strength combined with lightness but unsuitable in situations subjected to direct knocks. *Masonite*, an improved variety, is available in the form of boards and is used for wall lining as heat and sound insulation.

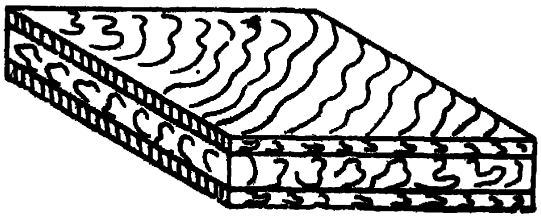
Different wood products made from plywood are illustrated below



(a) Batten board



(b) Fibre board



(c) Ply wood 3-ply

Fig. 4.31. Different wood products

The dimension of plywood boards are as below. The given dimension represent length, width and thickness. Other sizes have to be specially ordered. The length vary from ·90 cm to 240 cm, the usual length vary 90, 120, 150, 180, 210 and 240. Similarly the boards are available in width varying from 90 cm to 120 cm. The thickness for various "Ply" are as below :

3 ply ... 3 m to 6 m
5 ply ... 5 m to 9 m
7 ply ... 9 m to 16 m
9 ply ... 13 m to 19 m
11 ply ... 19 m to 25 m.

*Adhesives* are the materials used for bonding the surfaces of wood, metal, glass and plastics. The following are their main varieties :

1. Natural organic adhesives—animal protein, glues, blood albumin glues, casein adhesive, vegetable starch adhesive.

2. Synthetic organic adhesives—phenol formaldehyde, urea formaldehyde, products of cellulose, vinyl glues.

### 4.34 Destruction of trees growing on walls

Seeds of trees are left on walls by birds and some are carried by winds. They germinate, send out roots to the wall and cracks are made with the growth of trees. Their growth is prevented by cutting them when sap is down. Hole is made in stump in wall for sufficient quantity of saltpetre which is put there with water. Fire the stump when saltpetre is absorbed. The damaged wall is then repaired with liquid cement.

*Note*—Timber bedded in or resting on masonry should be coated with boiling coal tar and the ends of timber should have a space left on either side for free circulation of air round it. Timber should not be set within 2 feet of a flue. Unseasoned timber should never be used and it should be painted periodically when seasoned to prevent the absorption of moisture and also to beautify it. Factor of safety is 10 in case of timber. About $1{\cdot}5\ m^3$ of timber will go to one tonne of timber.

## 4.35 Indian timber trees

The particulars of the most commonly used timber trees in India are given in the table :

| Serial No. | Name of timber | Brief Description | Used in | Approximate wt. in gm/cm$^3$ (seasoned timber) | *Modulus of transverse strength (kg) |
|---|---|---|---|---|---|
| 1 | Arjun | Dark brown, heavy and strong, Found mostly in Central Provice and Santal Parganas. | Masts, spars, beams, rafters. | ·85 | 370 |
| 2 | Babool | Reddish brown, close grained and tough. Found in Sind, Rajputana and North Deccan. | Felloes of wheels, plough shares, tent pegs. | ·85 | 390 |
| 3 | Bakul | Pink, heavy and close grained. Found all over India. | Cabinet making. | ·96 | 280 |
| 4 | Bamboo | Strong & flexible, found all over India but abundant in Bengal & Assam. | Scaffolding, rafts, roofing, furniture. | ·40 | 435 |
| 5 | Banyan | Brown, neither strong nor durable except under water—aerial roots strong and tough. Found all over India. | Well curbs, aerial roots for tent poles, yokes. | ·58 | 270 |
| 6 | Black Palm | Reddish grey, durable specially under water. Found almost all over India. | Sleepers, well curbs, boats, agricultural implements. | ·75 | 260 |
| 7 | Chaplash | Yellowish brown, moderately hard, even grained. Found in Assam and Chittagong. | Ship buildings, canoes, masts, oars, house building, beams, planking, door frames, wheel, well curbs, furniture. | ·55 | 372 |
| 8 | Deodar | Yellowish brown, strong and durable, light and easily worked, most valueable timber. Found in Himalayas. | Roof, bridge building, Rly. sleepers, used for any purpose whatsoever. | ·48 | 292 |
| 9 | Guava | Hard, tough, light, flexible, not strong, fine grained. Found almost all over India. | Wood engraving, handles of instruments, toys. | ·74 | 280 |

* Breaking load applied at the centre of a piece 2·5 cm square with 30 cm.

| Serial No. | Name of timber | Brief Description | Used in | Approximate wt. in gm/$cm^3$ (seasoned timber) | *Modulus of transverse strength (kg) |
|---|---|---|---|---|---|
| 10 | Gumar | Pale yellow, strong and durable especially under water, easily worked. Found in Central and South India. | Planking, door panel, furniture, carriage, palanquins, yokes, well curbs. | ·57 | 202 |
| 11 | Indian Elm | Reddish, moderately hard and strong. Found almost all over India. | Door frames, carts, buildings. | ·96 | 326 |
| 12 | Iron wood | Reddish brown, extremely hard and very durable, not easily worked and resists nails, valuable timber. Imported mostly from Burma. | Houses, bridges, piles, posts, paying blocks, Rly. wagons, agricultural implements. | 1·0 | 292 |
| 13 | Jack | Yellow darkening with age, compact and even grained, hard and smooth. Found almost all over India. | Houses, boats, oars, well curbs, cabinet making, door panels. | ·7 | 350 |
| 14 | Jarul | Light reddish grey, hard, durable and easily worked. Found in Southern India, Assam and Bengal. | Scaffold board, boats, cart making, house building. | ·64 | 282 |
| 15 | Kail | Evergreen tree, moderately hard, durable, close grained. Found in Himalayas. | Furniture, house building, Rly. sleepers. | ·48 | 245 |
| 16 | Mahogany | Reddish brown, hard, easily worked and takes a good polish. Mostly imported from America. | Furniture making. | ·72 | 270 |
| 17 | Mango | Grey, hard wood in old trees. Found almost all over India. | Planks, boats, well curbs, door panels. | ·67 | 284 |
| 18 | Palms | Outside wood red, hard and strong. Found in almost all over India. | House building, furniture making. | 1·0 | 270 |
| 19 | Red cedar | Brick red, soft and even granted. Found in Assam, Chittagong & Ch. Nagpur. | Planks, door panels, well curbs, furniture. | ·48 | 252 |

* Breaking load applied at the centre of a piece 2·5 cm square with 30 cm span.

| Serial No. | Name of timber | Brief Description | Used in | Approximate wt. in gm/cm³ (seasoned timber) | *Modulus of transverse strength (kg) |
|---|---|---|---|---|---|
| 20 | Red wood | Yellowish brown, hard and strong, close grained. Mostly imported from New Zealand. | Clamps in masonry work, sleepers. | 1 | 460 |
| 21 | Sal | Brown, straight, hard, fibrous, close grained, lasts well underground and in water, durable, most useful timber except for ornamental works as it does not polish but it works well. Found in Himalayas, South and Central India. | House and ship building, bridges sleepers. | ·9 | 390 |
| 22 | Sandal | White or reddish, gives agreeable smell. Found in Assam, Bengal and Chotta Nagpur. | Well curbs, wheels, mallets, tent pegs, agricultural implements. | .92 | 396 |
| 23 | Satin wood | Yellow, very hard and durable, close grained. Found in Central and Southern India. | Furniture and ornamental works. | ·95 | 388 |
| 24 | Simul | White, light, loose grained, does not rot in water, poor wood. Found almost all over India. | Packing cases, canoes, well curbs. | ·45 | 292 |
| 25 | Siris | Dark brown, hard and durable. Found in Northern India. | Posts, beams and furniture. | 1 | 240 |
| 26 | Sissu | Rich dark brown and strong. Found all over plains, Central and Northern India. | Carriage and boat building, furniture, agricultural implements, sporting requisites. | ·8 | 360 |
| 27 | Sundari | Dark red, hard, tough, durable, elastic and close granted. Found in Sunderbans of Bengal. | Piles, felloes, poles, carriage shafts. | 1 | 590 |
| 28 | Tamarind | Dark brown, durable, knotty. Found almost all over India. | Sugar mills, tool handles, well curbs, carts, brick burning. | 1 | 386 |

* Breaking load applied at the centre of a piece 2.5 cm square with 30 cm span.

| Serial No. | Name of timber | Brief Description | Used in | Approximate wt. in gm/cm³ seasoned timber) | *Modulus of transverse strength (kg) |
|---|---|---|---|---|---|
| 29 | Teak | Dark brown or reddish brown, moderately hard; seasons, works & polishes well; possesses oil which acts as creosote and so prevent dry rot; very strong, durable yet light and easily worked; shrinks little and takes smooth polish; does not corrode iron fastenings; durable in all situations; most valuable timber in the world. Malabar teak is heavier than Burma teak. Indian teak is not very durable. Found in Central and Southern India. | Houses, door frames and panels, well curbs, piles, posts, beams, rafters, mallets, tent pegs, cart wheels, ploughs, agricultural implements and works of all descriptions. | ·72 | 308 |
| 30 | Toon | Rich reddish brown, light and easily worked. Found in Assam. | Furniture & cabinet works, packing cases. | ·53 | 162 |

* Breaking load applied at the centre of a piece 2·5 cm square with 30 cm span.

### 4.36 Foreign timbers in India

Some foreign timbers are imported in India from Europe, America, Australia and New Zealand. The most important ones are iron wood, ash, oak, pine, mahogany, red wood and teak.

### 4.37 Timber suitable for various uses

Agricultural tools—Ash, babul, iron wood, sundari, temarind, teak.

Cart wheels—Babul, shishu, sundari.

Door and window frames—Teak, sal, iron wood.

,, ,, shutters—Teak.

Furniture—Mahogony, shishu, teak

Packing cases—Simul, toon,

Piles—Sundari, teak,

Rly. sleepers—Deodar, sal shishu.

Scaffolding—Bamboo, sal.

Sports goods—Ash, oak, shishu.

Tent Pegs—Babool, Sandal, teak.

Well curbs—Jack, mango, simul, tamarind.

### 4.38 Advantages of timber constructions

1. It can be easily worked with tools to any size.

2. Structural connections are easily made in timber constructions.

3. It is stronger than other materials of construction in proportion to weight.

4, It is largely used for decorative and attractive interior fittings of artistic design.

5. The economy of timber construction is generally recognised.

6. The houses built of timber are cool in summer and warm is winter.

7. The durability of timber well protected is unquestionable.

8. Timber construction is well-known for lighıness, strength and durability.

### 4.39 Bamboo

Another important forest product, naturally grown in the forest and used as a building material in the countrv and elsewhere is bamboo.

Though bamboos are spread all over the world and grow upto 3000 metre heights above the sea level very dense bamboo forests exist in South East Asia i.e. India, Burma, Thailand, China and adjoining islands. In addition to construction of temporary structure of a cheap quality, bamboo is used almost for all parts of the house construction except near fire places. In addition to the building construction bamboo is used in the manufacture of paper, as well a number of cottage industries such as poles, toys, umbrella handles, mats, chicks and walking sticks.

## EXERCISE IV

### A. M. I. E. (I) Examination Questions—

1. How do you select good timber from a godown ? (May 1962)

2. (a) Explain the term 'seasoning of timber'. Why is it necessary ? What are the different methods adopted for 'seasoning of timber' ? Comment on each.

(b) Name a few varieties of timber used in building and bridge construction, stating their special properties. (Nov. 1961)

3. (a) Explain the term seasoning of timber. How is timber seasoned by kiln-drying process ? (b) Describe teak as the best building material, mentioning its special properties and uses. Name also the places, where it is available in India. (May 1961)

4. (a) What is seasoning of timber ? How is it done on a large scale ? (b) Mention three timbers that are mostly used as engineering materials with their relative advantages and availability. (Nov. 1960)

5. Write short notes on important varieties of timber and their properties and places of availability in India. (May 1960)

6. Distinguish between 'dry rot' and 'wet rot'. What steps are taken in executing woodwork to see that these defects do not occur ? (May 1960)

7. Give a brief account of the decay and preservation of timber. What suggestions do you propose for improvement in construction to avoid decay of timber, and what measures are to be taken, when it has occurred ? (Nov. 1959)

8. Write short notes on (a) kiln seasoning of timber, (b) creosoting of timber. (May 1958)

9. Enumerate the properties of good timber. Briefly describe the various methods used for the preservation of timber. (Nov. 1957)

10. Explain the purpose of seasoning timber. Briefly describe the various methods by which it is affected commenting on each. (May 1957)

11. (a) What are the common defects in timber ? Describe the various methods employed in preserving timber and increasing its durability.

(b) What is plywood ? Describe how it is manufactured. State the advantages of plywood as a structural material over ordinary timber. (Nov. 1956)

12. What are the characteristics of good timber ? What is the object of seasoning it ? Explain briefly the different methods of seasoning timber. (May 1956)

13. Give the characteristic differences between (a) hard wood and soft wood, (b) heart wood and sap wood. Which class of timber is suited for exterior of buildings and what protection do they require from weather ? Point out the causes that lead to warping, shrinkage, and distortion in scantlings ; how are they avoided ? (May 1955)

14. Write short notes on the defects commonly noticed in timber. What is meant by seasoning of wood and how does it influence its behaviour ? What advantages are gained by using multi-ply wood instead of whole timber ? How is plywood formed ? (Nov. 1954)

15. Name the various methods of seasoning timber. Describe in detail the method you consider best, giving reasons for your answer. How does the period of felling affect the strength of timbers ? (May 1954)

16. Enumerate the principal destructive agents which generally attack timber in India and describe the methods generally adopted for preservation of such attacks. Also give the names of timber which has natural properties to resist such attacks. (Nov. 1953)

17. (a) What are hard woods and soft woods ? Name a few species of each. How do you differentiable them ? (b) What are the causes of decay in timber ? (c) What are the requirements of a good wood preservative ? What are the main types ? (May 1953)

18. What are the characteristics of good timber ? State usual defects noticed, giving reasons for the occurrence for these. State the general characteristics and uses of the following timbers : teak, sal, sissu, deodar and jarool. (Nov. 1952)

19. (a) Distinguish between plywood, battenboard and fireboard by means of sketches. Explain what is masonite.

(b) What are the common defects in timber ? How would you find whether an apparently sound log of timber is hollw inside ? (May 1952)

20. What considerations will guide you in selecting a suitable timber for building purposes from a timber godown ? Discuss the various methods of seasoning and preserving timber. (Nov. 1951)

21. How is decay in timber caused ? Describe a preservation treatment of a wooden railway sleeper. (May 1951)

22. (a) Define, with sketches where necessary, the following : heart wood, sap wood, medullary rays, rindgall, wet rot.

(b) How many cu. ft. of timber go to a ton ?

(c) Timber is sold in India in various forms and sizes. Give their names and dimensions. (Nov. 1950)

23. (a) Give the cross-section of a mature tree and name the different parts. What is the best season for felling a tree ?

(b) How can sap wood in trees be improved in strength and durability ? What is the object of seasoning timber ? (April 1950)

24. What are chief characteristics and engineering use of the following timber :

(i) Shushan, (ii) Deodar, (iii) Teak, (iv) Sal. (May 1963)

25. (a) Explain the term seasoning of timber. What are the different methods adopted for the principal timbers in India for constructional purposes. Describe with sketches one of the methods.

(b) What is plywood and where is it used with advantage ? (Nov. 1963)

26. Mention the various defects in timber. Write a note on the preservation of timber. (May 1964)

27. (a) Describe the various methods for the preservation of timber.

(b) What are the common uses of timber in building industry. (Nov. 1965)

28. (a) What are the characteristics of good timber ?

(b) State the principal causes of decay of timber.

(c) What is plywood ? State its use in modern building. (Nov. 1966)

## Engineering Services (I) Examination Questions—

29. (a) Sketch a neat cross-section of the trunk of a timber tree and name the different parts. (b) If a badly seasoned log of timber is sawn into planks by four saw cuts, show by a neat sketch the alterations in form that are likely to occur in them after a few years. (c) What is plywood ? Describe its manufacture briefly with

sketch. State the advantages of plywood as a structural material over ordinary timber. (1961)

30. (a) State the cause of 'dry rot' in timber and give particulars of prevention and treatment. (b) Explain why timber used for structural purposes should be properly seasoned and describe briefly the procedure in 'air-seasoning' and 'kiln seasoning of timber from the green state. (1958)

## Other Examination Questions—

31. What is the best time for felling a timber tree and why ?

32. How can sap wood of trees be improved in strength and durability ?

33. Explain the terms, illustrating your answer by neat sketches whenever possible :—Heart wood, sap wood, dry rot, wet rot, heartshakes, starshakes, rind-Galls, upsets, medullary rays.

34. What are the characteristics of good timber ? What is the object of seasoning timber and what changes are effected by seasoning it ?

35. How timber used in houses decays and how can it be prevented ?

36. What effect has partial immersion in water on timber ?

37. Describe the different ways that you know to preserve wood from decay when burried in ground.

38. Describe Bethel's process of preserving timber.

39. How is timber protected from (a) moisture and (b) internal decay ?

40. Describe any method of protecting timber from white ants.

41. What is the object of painting wood work and what is the effect of paint upon unseasoned timber ?

42. Name six kinds of Indian timber generally used in your State for building purposes giving short descriptions of their characteristics and uses.

43. Name the trees which produce timber suitable for works under water or in damp places and give a brief description of each.

44. Distinguish between sal, mahogany, bamboo and teak as timber and compare them in regard to durability and cost.

45. How many cubic meter of timber will go to a tonne generally ?

46. What are the characteristics and qualities of sal and teak ? What places supply good sal and teak wood in your State ? Which of these would you prefer for making beams. door frames, verandah posts and door shutters ? Which is the stronger ?

47, How is timber for engineering and building purposes clssified ? Classify and describe the following timber, giving the principal uses of each : Deodar, chir, teak, sal, toon, sissu, bamboo, mango, neem, babool, sundari, jack, simul, jarul aud mahogany.

48. If a badly seasoned log of timber is sawn into planks, show by neat sketches the alteration in forms that are likely to occur in them.

49. Show graphically how you would cut a round log of timber to obtain strongest rectangular beam and also stiffest rectangular beam.

50. What timber is best suited for (a) tent poles, (b) tent pegs, (c) cart wheels, (d) beams, (e) well curbs, (f) plies and (g) doors and windows ?

# Chapter 5

## METALS AND ALLOYS

**5.1** The metals generally used by the engineer are *iron*, *copper*, *lead*, *zinc*, *tin*, etc. These metals are not found to any great extent in the pure metallic state but are found in combination with oxygen as oxides, sulphur as sulphides and with carbonic acid as carbonates. These compounds of metals with non-metallic elements are called ores. These are extracted from the earth by the mining operations.

India is known to have produced wooz steel as early as 3000 B.C. It has been mentioned in ATHARVA VEDA as लोहम्. The Delhi pillar erected about 400 A.D. by Kumar Gupta I has not been affected by weathering even till today. It is however, unfortunate, in spite of the above initial advantage our production per capita is less than $\frac{1}{20}$th of that of Russia and about $\frac{1}{60}$th of that of U.S.A. which produce about 900 kg.

Pure iron has a denses of 7·9, tensile strength 2800 $kg/cm^2$, BHN =80 and melts at 1537°C.

Iron and steel though by usage are termed together but they are two different things with different constituents and different methods of manufacture.

About 25% of the world's reserve of iron ore are in India and these deposits are of one of the best quality.

## 5.2 Metallurgy

It is the art of separating metal from their ores and subsequently purifying them to suit to the various purposes of manufacture.

Iron is the most abundant, cheapest, strongest, most magnetic and the most indispensable substance from constructional point of view.

## 5.3 Nomenclature of iron

Iron is divided into three classes depending on the chemical composition, mechanical properties and method of manufacture :

1. *Cast Iron* (C.I.)
2. *Wrought Iron* (W.I.)
3. *Steel.*

These are *ferrous metals.*

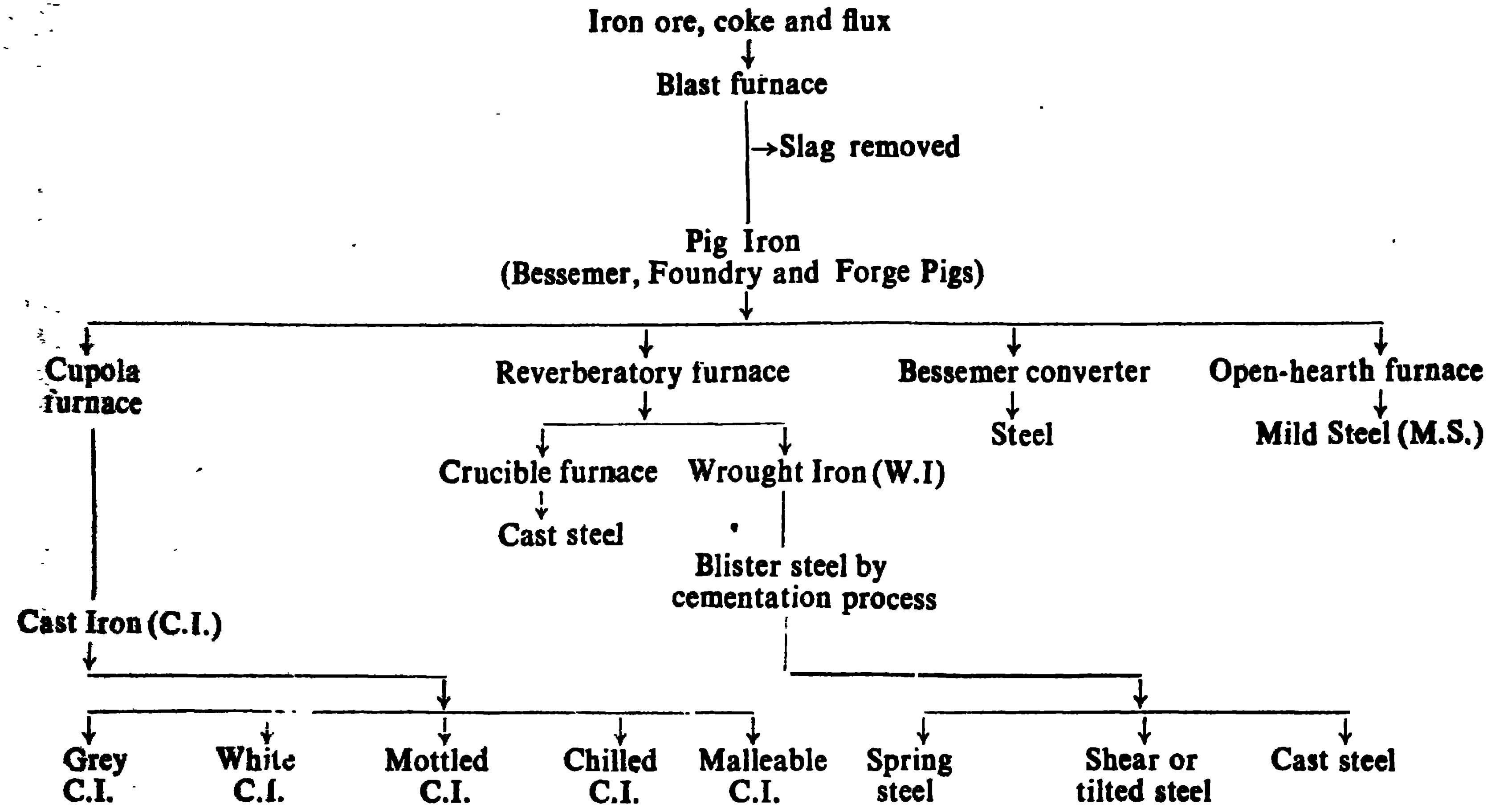
## 5.4 Iron ores

Iron is most abundant and widely distributed element. The ores must be rich, pure, plentiful and easily reduced for the economic production of the metal. All ores are more or less mixed with impurities, such as, carbon, silicon, sulphur, phosphorus and manganese. There are five important iron ores : ***magnetite, haematite, limonite, siderite*** and ***pyrites.***

## 5.5 Composition and sources of principal iron ores with percentage of iron

| No. | Iron ores | Composition | Maximum % of iron | source |
|---|---|---|---|---|
| 1. | *Magnetite (Magnetic iron ore or load stone)* | $Fe_3O_4$<br>Ferroso-ferric oxide. Iron and oxygen. | 72 | Exists in Sweden and Norway in large quantities. Occurs in Gya but not worked. |
| 2. | *Red Haematite* | $Fe_2O_3$<br>Anhydrous ferric oxide. Iron and oxygen. | 65 | Richest British iron ore. Occurs in Manbhum district but not in abundance. |
| 3. | *Limonite (Brown Haematite)* | $2Fe_2O_3 . 3H_2O$<br>Hydrated ferric oxide. Iron, oxygen and water. | 60 | Exists in Northamptonshire and Spain in abundance. Occurs in Manbhum and Singhbhum.<br>Worked at Barakar & Jamshedpur. |
| 4. | *Siderite (Spathic iron ore).* Generally mixed with carbonate of lime and magnesia. | $FeCO_3$<br>Carbonate of iron. Iron, oxygen and carbonic acid. | 48 | Exists in Durham, Somerset and Syria. |
|  | *Clay Iron Stone* | Ferrous carbonate mixed with clay and sand. Iron, oxygen, carbonic acid and clay. | 45 | Chief ores of Great Britain. Occurs in Raniganj coal field & Hazaribagh. |
|  | *Blackband* | Clay iron stone blackened by bituminous matter. Iron, oxygen, carbonic acid, clay and bituminous matter. | 40 | Occasionally met within Burdwan. |
| 5. | *Iron Pyrites* | $FeS_2$<br>Sulphide of iron. Iron and sulphuric acid. | 47 | Occurs in Manbhum and Singhbhum. |

## 5.6 Scheme of iron manufacture



## 5.7 Manufacture of pig iron

Pig iron is an impure iron. It always contains foreign substances, such as, carbon, silicon, sulphur, phosphorus, and manganese. The operations for the manufacture of pig iron from ores are : 1. *dressing*, 2. *calcination* and *roasting*, and 3. *smelting*.

1. *Dressing* : The ores brought up by mining operation are broken up and impurities or clay adhering to them are knocked off.

2. *Calcination* and *roasting* : After dressing, the broken up ores are calcined and roasted in heaps or kilns to drive off moisture and carbonic acid. Roasting is not necessary if the ore be an oxide.

3. *Smelting* : The calcined ore is then mixed with appropriate flux and reduced in a high *blast or smelting furnace* (Fig. 5.1) and then it comes out in the form of pig iron. The large upright furnace lined with firebricks is first filled to a certain height with fuel. When this is burning, ores mixed with appropriate flux or reducing agent and fuel (coke or coal) are alternately put in from the top. A high temperature of about 1500°F is maintained in the furnace by hot blast introduced at the bottom. Flux mixes with impurities (gangue) in the ore, forms fusible slag which floats on the surface of molten iron and is removed through slag hole. The slag has the following composition : lime CaO 45%, silica $SiO_2$ 35%, alumina $Al_2 O_3$ 12% and the remaining are magnesia MgO, calcium sulphate $CaSO_4$, manganese oxide $MnO_2$ and oxide of iron FeO. When a considerable quantity of liquid iron is collected the furnace is tapped at intervals of 8 to 10 hours and the iron runs into a long channel formed in sand called '*sow*' and having branches, called '*pig*' about 3 feet or 1 m long on each side. The solidified iron in the branches is removed and sold in the market to founder or iron manufacturers as *pig iron*. The blast furnace works continuously day and night until it requires overhauling.

*Blast* of air is forced into the furnace through tuyers by a blowing engine for burning the fuel inside. When blast of air is cold as in older type of furnace it is called *cold blast* but in modern furnace escaping gases are utilised to heat the air forced into the furnace, it is then called *hot blast*. In some progressive work blast is dried and so it is called *dried blast*. Cold blast is seldom used now-a-days except for production of castings of great soundness and high class wrought iron. There is a great saving of fuel and a great heat is obtained due to hot blast but if care be not taken an interior quality of iron is produced as

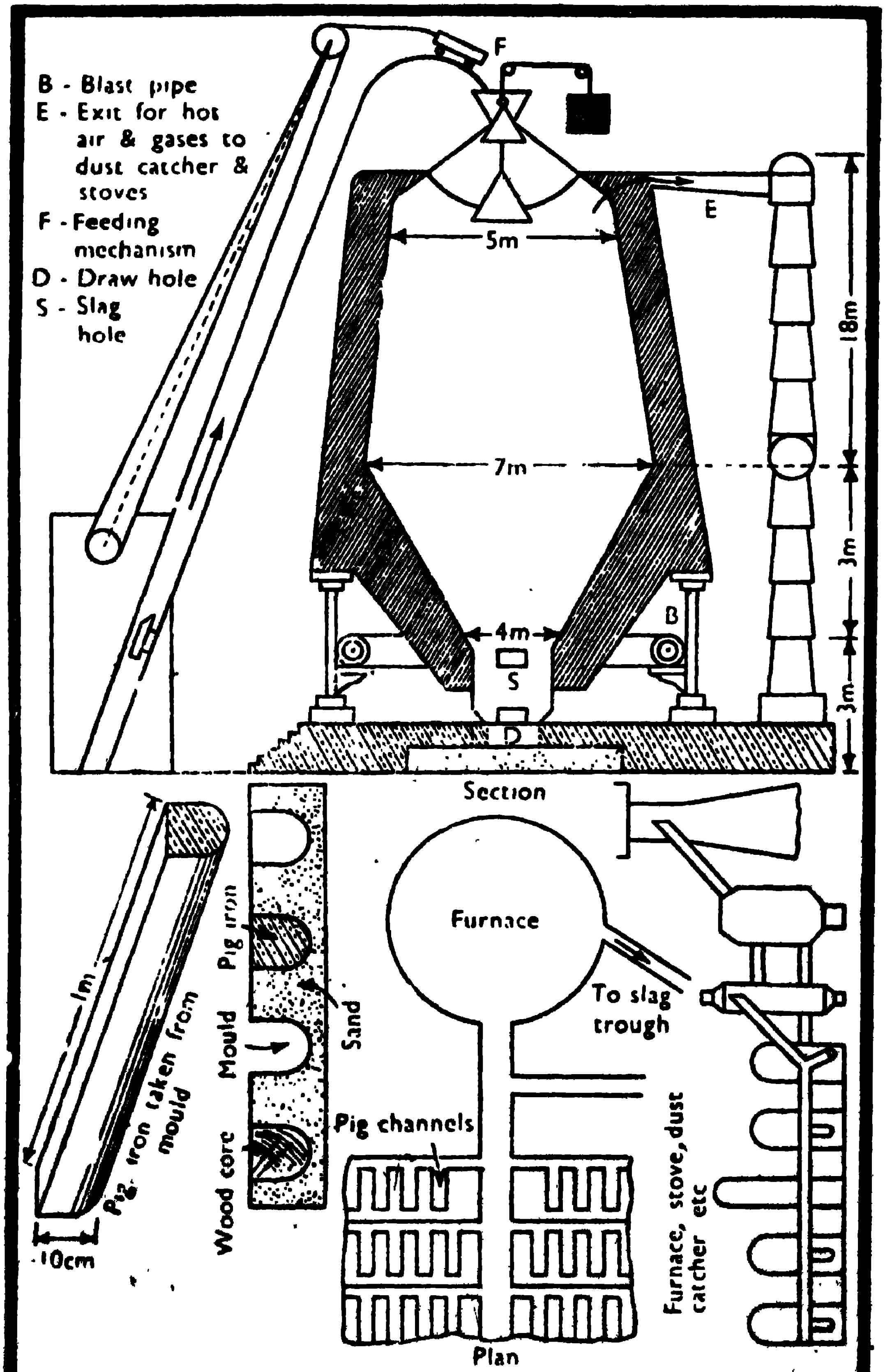


Fig. 5.1 Blast furnace

the very thin fluid of metal due to hot blast runs out with some liquid impurities.

If the impurities be clay, limestone is added as *flux*, if it be limestone, clay is added and if it be quartz, limestone and argillaceous iron ores are added.

5.7.1. *Action in Blast Furnace*. The combustion of fuel in the furnace forms carbon dioxide, which unites with the carbon of the fuel owing to the intense heat of the furnace and forms carbon monoxide. The monoxide is the real reducing agent in the reduction of the metal. $CO_2+C=2CO$ and $Fe_2O_3+3CO=2Fe+3CO_2$.

5.7.2. *Classification of Pig Iron*. The varieties of pig iron are classed under four heads:

1. ***Bessemer pig*** is made from haematite ores. It should be free from sulphur, phosphorus and copper as far as possible, but silicon and manganese in a small percentage will improve its quality. It is used in the manufacture of steel by Bessemer process.

2. ***Grey or Foundry pig*** is produced when the furnace is properly provided with fuel and at a very high temperature. Its fracture is of grey colour. It contains considerable proportion of free carbon. It is mostly used by the iron founder.

3. ***White or Forge pig*** is produced when fuel is insufficient or temperature is low and also when there is much sulphur either in ore or fuel. It is generally run from blast furnace into iron moulds instead of sand so as to keep it free from the impurities of sand. It is free from uncombined carbon and so it is unfit for superior castings but useful only for the conversion of wrought iron.

4. ***Mottled pig*** lies between grey and white varieties. It has a larger proportion of combined carbon, is stronger and has a mottled appearance on fracture. It is used only for the heaviest classes in foundry work, and is unsuitable for light and ornamental castings.

Classification from the consideration of use:

1. *Acid Pig Iron*: This is made from Haematite pig iron and is used for manufacturing high duty castings, ingot mould castings and acid steel.
2. *Basic Pig Iron*: It has two grades namely standard basic (·75--1·25% Si) and low silicon (·75% Si). It is used for basic steel and steel castings.

3. *Foundry Pig Iron* : The four grades of this pig iron are given in I.S. 224 and used for grey iron castings.
4. *Forge Pig Iron* : Si content 1·5% used for the manufacture of wrought iron products.
5. *Pig Iron (Charcoal)* : 7 grades given in I.S. 225. It is prepared from magnetite ore ($Fe_3O_4$).

## 5.8 Manufacture of cast iron

*Refining—Cast iron* is obtained by purifying foundry pig iron to some extent by remelting it in a *cupola furnace* (Fig. 5.2) similar to small blast furnace with limestone used as a flux which combines with some of the impurities left with pig iron and removes them in the form of slag. The molten metal is then run into moulds of required shapes. Cast iron contains 2 to 5 per cent of carbon with other impurities, such as, silicon, sulphur, phosphorus and manganese in small quantities.

The cupola is a shaft furnace, the fuel and charge (foundry pig iron) being in contact. The furnace consists of a 12 m high and 1·5 m dia steel cylinder, the inside of wheel is lined with fire bricks, while the top is open. The bottom is closed by means of two drop bottom doors which are semi circular. A common wind belt around the furnace stack feeds air to the tuyers located above the tapping hole, the height of which is determined from the amount of the molten metal that can accumulate in ore tapping. The top of the cupola has a Cowl and spark arrester.

The capacity of the cupola is given in term of output of the molten material per hour. On an average the following will be required to melt one tonne of iron :

(a) air 700 $m^3$,

(b) limestone 20 kg,

(c) coke 1 quintal.

5.8.1 *Classification of Cast Iron*. There are six principal varieties of cast iron :

1. *Grey cast iron* is made from foundry pigs. It is of grey colour with large grains, melts readily and so most suitable for superior castings. It rusts most amongst the first three varieties.

2. *White cast iron* is of silver colour, very hard and brittle, melts with much difficulty and so is unsuitable for delicate castings.

3. *Mottled cast iron* is obtained by the cementation process which consists in heating cast iron to a red heat with powdered red haematite in an oven for increasing its toughness. It is generally done in the case of small castings. It is the mixture of grey and white varieties. The fractured surface is either white with grey patches or grey with white patches.

4. *Chilled cast iron* is one where some parts are hard and some parts are soft. The running surface of a cast iron railway wheel is chilled and covered with a hard skin of white iron but the other parts of the wheel are of tough grey iron. Pieces of cold iron of suitable shapes, coated with loam, are placed in the moulds over these parts which are to be hardened. Its surface where touched is suddenly chilled and converted into white iron.

5. *Malleable cast iron* is made by extracting a portion of carbon from cast iron for its toughness. This is done in case of some castings by embedding those in powdered red haematite and raising to a bright red heat in an annealing oven. These are specially suitable for intricate forms, such as, toothed wheel, screw propeller, gun locks, pokers, tongs, etc., which cannot be forged in wrought iron without much difficulty and expenses.

6. *Toughened cast iron* is obtained by melting cast iron and $\frac{1}{4}$th to $\frac{1}{7}$th of its weight of wrought iron scrap.

5.8.2 *Casting.* The full description of the art of the iron founder does not come within the range of this small book. The simplest form of the process of iron founding is however described here so as to enable the reader to understand the points to be observed in examining and testing the different types of castings.

5.8.3 *Casting in Sand.* Casting used in engineering works are generally made by pouring molten iron into moulds made in sand or loam in which the impression of the article required has been formed by wooden or iron *pattern.* These may be made in the kutcha floor of the foundry but in case of small castings these are usually made by filling sand into iron boxes with top and bottom called *flasks*, made into two similar parts, one fits over the other. The wooden or iron pattern about 1 cm per metre larger in every direction than the finished casting so as to allow for contraction in cooling, is placed in the lower flask so that half of it rises above the top of latter and the space round the pattern into the box is tightly packed with damp sand, the surface of the pattern having been dusted with dry parting sand. The upper flask is then put over the lower one and also tightly packed with damp sand round the pattern. The upper box can then be lifted up with its sand in it and pattern can be taken out. The two halves of the mould are carefully dried and the inside of the mould is dusted over with charcoal powder to prevent the metal from being chilled by coming in contact with wet sand. Then each box will have the mould of half the article and will make a complete mould when both joined together. Bigger holes are left in sand to pour the iron in and smaller ones for the escape of air in the mould and gases evolved when molten metal is poured in. If the air and gases are allowed to force through the molten metal then it will be full of flaws and so unsound. Bigger holes are so arranged that metals run together from different parts at the same time otherwise iron will not run into one mass but will form what is called *cold shut*. Casting is cleaned by wire brush and the irregularities are removed by filing, the various types of castings are *centrifugal casting*, *chilled casting*, *Die casting*, and *Malleable casting*.

5.8.4 *Examination of Casting*. In examining casting the following points may be taken into consideration :

1. Air bubbles or flaws filled in are a common and dangerous source of weakness. These will cause a dull sound by tapping their surface lightly with a hammer, but a good casting will ring sound when struck.

2. The recent fracture of iron should be of fine grain, bluish grey colour and metallic lustre.

3. The outer surface should be smooth and clear, and the edges perfect and sharp.

4. Casting should be sufficiently soft to be drilled or chiseled.

5. Iron is hard and brittle if the fragments fly off and no sensible indentation be made when gently struck with a light hammer.

## 5.9 Manufacture of wrought iron

Wrought iron is almost pure iron containing not more than 0·15 per cent of carbon with other impurities in very small quantities. This metal played in its days, a very important part in engineering works but now-a-days it has been displaced by mild steel to a great extent. It is now almost entirely confined to ornamental use. The manufacture and physical qualities of wrought iron may be regarded as having a historical value rather than a practical one. However it is advisable to retain the description of a material which played so important a part in its days and moreover some wrought iron structures are still in existence and giving good service. It is generally manufactured from pig iron. It is a laborious and expensive process involving several operations, such as, 1. *refining*, 2. *puddling*, 3. *shingling*, and 4. *rolling*. It may be extracted direct from ore by operations dressing, roasting, smelting, refining, puddling, shingling and rolling. Forge pig is generally used for its manufacture and can be converted direct by puddling process.

1. *Refining* consists in directing a strong current of air to well stirred molten pig iron for thorough oxidation. Then it is cast into moulds and rendered brittle by cooling suddenly.

2. *Pudding* consists in converting refined pig iron into wrought iron by melting it in a *reverberatory or pudding furnace* (Fig. 5·3). The molten metal kept clear of the fuel in the furnace lined with iron ore is well mixed with oxidising substances, such as, haematite ore, oxide of iron, forge scales, etc. and is subjected to intense heat and a strong current of air. Carbon left in iron is converted into carbonic acid gas and passes through the chimney. Silicon is also oxidised and removed in the form as slag through slag hole. The purer metal acquires stiffer consistency and can be raked up into puddle balls on the floor of the furnace. In this furnace the metal is heated by the burning of gases instead of by direct contact with solid fuel as in the case of blast furnace and so in this process sulphur dioxide giving off on conbustion of fuel containing sulphur is not taken up by the iron. The necessity for a non-sulphurous fuel, such as, charcoal is therefore eliminated.

3. *Shingling* consists in forcing out any slag remaining in the puddle ball either by tilt, helve or steam hammer and also welding the particles of iron together into a 'bloom'.

4. *Rolling* consists in passing the bloom through grooved rollers converting it into puddle bars or rough bars which are of inferior quality. Sizes of the bars are generally 10 cm × 10 cm × 3.5 m. Rough bars in short lengths are rendered more homogeneous and fibrous and thus improved in qualities by process of piling (fastening together with wire), reheating and rerolling. This improved iron is of grade known as *merchant bar iron*. Repeated cutting, piling, heating and rerolling into the final shape yield '*best bar*', '*best best bar*', and '*best best best bar*'. *Scrap bars* are made from useless short pieces by welding and rolling together into a single bar. *Best scrap* and *best best scrap* are produced if the scrap used be clean and of good quality.

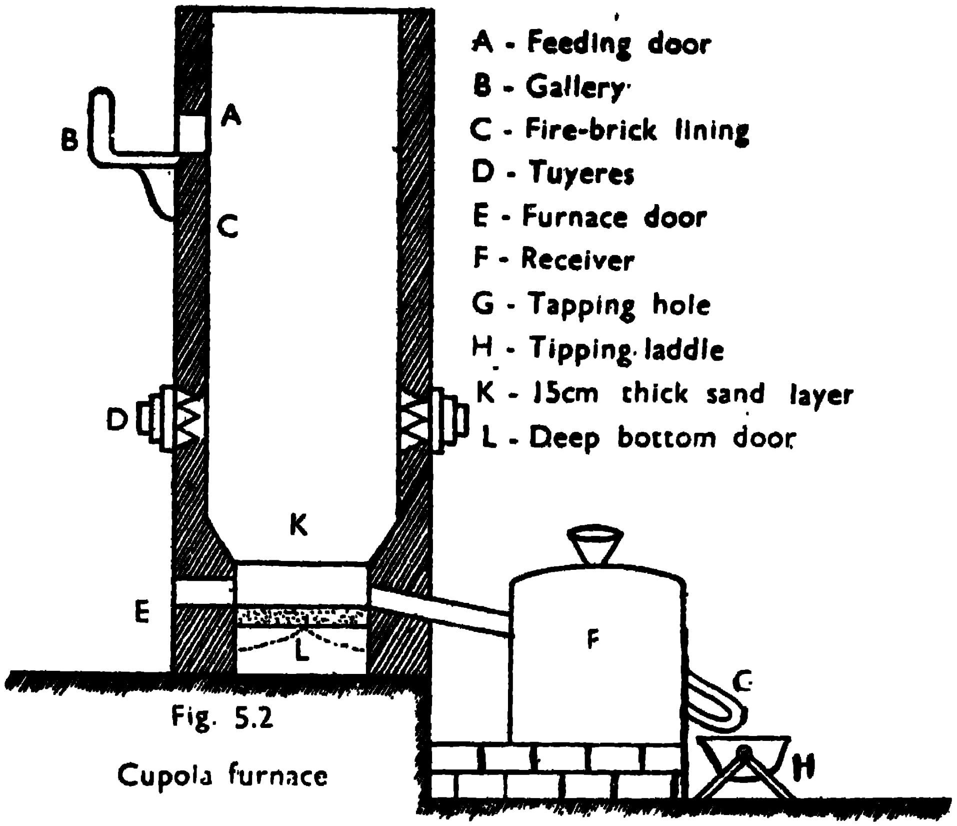


Fig. 5.2

Cupola furnace

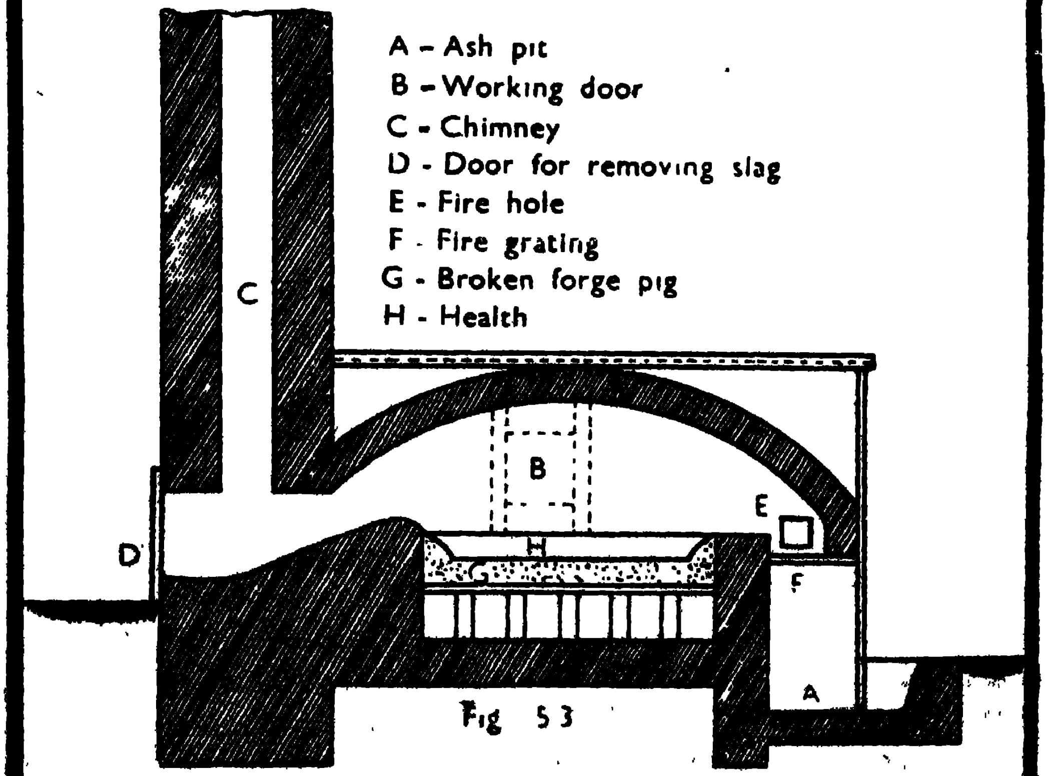


Fig 5 3

Reverberatory furnace

5.9.1 *Defects in Wrought Iron.* Defective wrought iron may be *cold short* or *red (hot) short.*

*Cold short iron* is very brittle when cold and cracks if bent double, although it may be worked at a high temperature. This defect is due to the presence of an excess of phosphorus.

*Red short* or *hot short iron* cracks when bent or finished at a red heat but is tenacious when cold. This defect is due to the presence of excess of sulphur. Red short iron is of no value for welding purpose.

5.9.2. *Imperfections in Finished Wrought Iron,*

1. *Rough edges* are a sign of red shortness.
2. *Spilly places* are irregularly spotted parts due to imperfect pudding.
3. *Blisters* are due to reaction between oxide of iron and carbon in wrought iron.

## 5.10. Manufacture of steel

Steel may be classed into *high carbon steel* or *hard or cast steel,* and *low corbon steel* or *mild steel.* Steel is manufactured either by adding the required amount of carbon to wrought iron or by partialy refining pig iron and removing a portion of its carbon until the required amount remains. The principal methods used for the manufacture of steel of different descriptions are : 1. Cementation process, 2. Crucible process, 3. Bessemer process, 4. Open-hearth process, and 5. Electric smelting process.

5.10.1 *Cementation Process.* By this process pig iron is completely decarbonised into an almost pure wrought iron and then converted into steel by adding proper percentage of carbon.

Steel is produced by placing bars of the pure wrought iron between layers of charcoal powder in a doom shaped furnace known as cementation furnace and subjecting those to a very high temperature for a week or two, according to the quality of steel required. The wrought iron combines with the carbon and is covered with blisters. The steel obtained is known as *blister steel* and it is full of fissures and cavities.

5.10.2 *Crucible Process.* By this process either fragments of blister steel or short lengths of wrought iron bars mixed with charcoal are heated in fire-clay crucibles and the molten iron is run into iron moulds. The steel obtained is known as *cast steel.* It is uniform in quality and extremely hard.

**5.10.3** *Bessemer Process.* By this process steel is manufactured by removing the proper porportion of carbon from pig iron or by completely decarbonising pig iron and then adding proper percentage of carbon. Softer variety of steel is obtained.

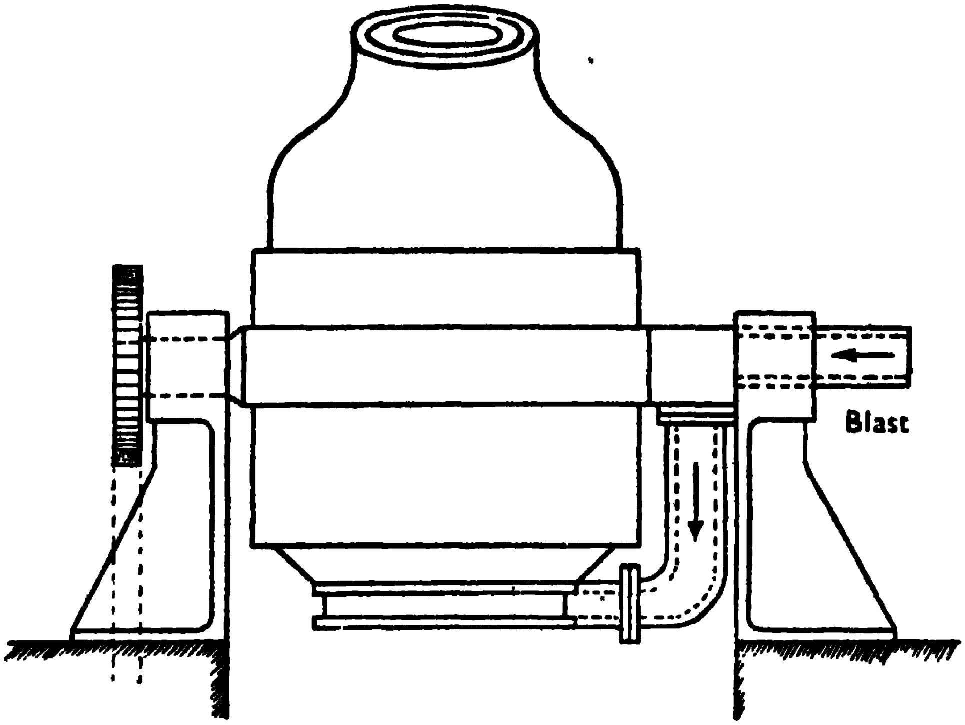
There are two varieties of the Bessemer process :

(a) *Acid Bessemer process* so called because the converter is lined with acid materials, such as, clay, quartz and ganister.

(b) *Dephosphorising or Basic Bessemer process* so called because the converter is lined with basic materials, such as, calcined magnesium, limestone and tar.

(a) *Acid Bessemer process.* The *converter* (Fig. 5·4) is a pear shaped vessel made of boiler plate lined inside with firebricks or some other refractory materials and capable of revolving about a horizontal axis. It is first heated by a charge of burning coke which is racked out after a time. About 20 tonnes or tonnes of Bessemer pigs are melted in a cupola and run into a converter tilted into horizontal position to receive the charge. In some works molten metal is run into the converter direct from the blast furnace. A blast of air is then forced through the metal in the converter through openings provided for tuyeres at the bottom, turned into vertical position and the blast is kept on for few minutes till nearly all carbon has been burnt out and then the required carbon may be added by recarburizing or the process may be stopped when the carbon content comes to that of the required product. The blower knows when to end the process, judging by the brilliancy, colour, sound, sparks, smoke and other indications of the flame. In the first case the converter is again swung into horizontal position, blast shut off, required proportions of manganese and carbon are added, turned into vertical position and blast turned on for a short-time for thorough mixing of iron. Bessemer steel thus produced is poured out and run into moulds.

(b) *Basic Bessemer process* resembles the acid Bessemer process but the inside of converter is lined with basic material. By this process poor ore containing a large proportion of phosphorus or sulphur can be converted into steel. Calcined lime is added and so phosphorus or sulphur partly passes out as fumes and partly unites with lime so as to pass out as slag. Temperature in converter is 2200°F.



Front elevation of Bessemer converter

R - Converter receiving charge
W - " in working position
D - " " discharging "

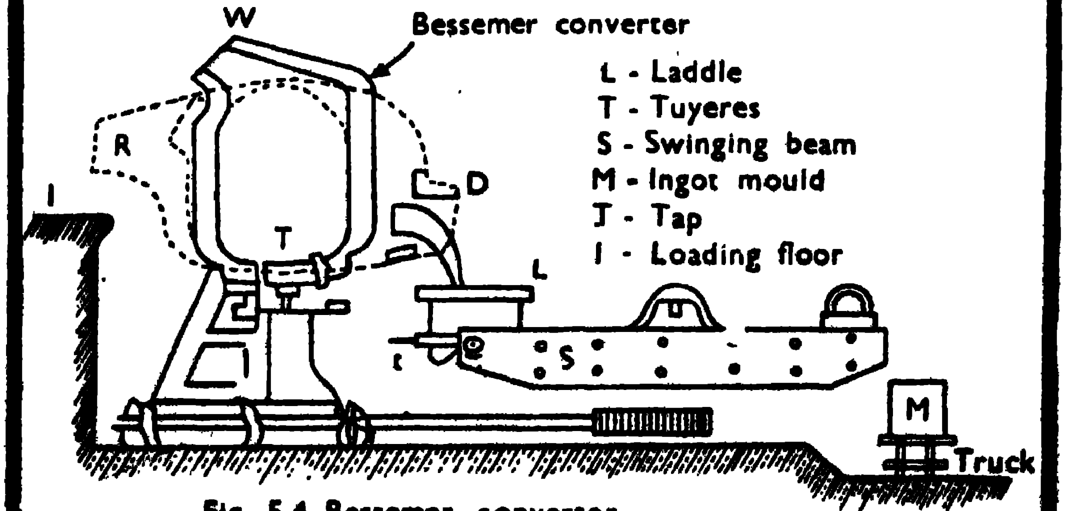


Fig. 5.4 Bessemer converter

In it steel heats the converter whereas furnace heats the steel in Open-hearth and Crucible processes.

5.10.4. *Siemens or Open-Hearth Process.* By this process steel is manufactured from iron ore rich in oxides, pig iron and steel scraps. Better grade of soft steel is obtained.

It may be either acid or basic like the Bessemer process. There are two such processes .

(a) *Siemens process* consists in the manufacture of steel by fusion of pig iron and pure ore in the Open-hearth for about 18 hours, the impurities of pig iron are oxidised by the oxygen of the ore and also by furnace gases.

(b) *Siemens Martin process* consists in the manufacture of steel by melting a mixture of pig iron and scraps of wrought iron and steel. Carbon is lessened due to the dilution with less impure scraps and also the oxidation of the fused metal by the furnace gases. In the Open-hearth process the steel is made on the hearth of *regenerative gas furnace* (Fig. 5.5). It resembles a very large puddling furnace. The fuel used is *producer gas* and it is brought to the hearth H of the furnace through a passage entirely filled with checkered red hot silica brick-work. Most intense heat is developed by the combustion of the gas as it mixes with the streams of hot air inside the furnace. A temperature of 2500°C may be maintained in this furnace but in reverberatory furnace temperature is only 2000°C. The generative principle consists in utilisation of the heat of the escaping gas in reheating the silica bricks in air and gas passages. When the furnace is working, gas and air pass through two of these regenerators on their way to furnace and silica bricks of other two regenerators are heated by escaping gas before leaving through the chimney. The direction of flow is reversed after about an hour or so. An enormous amount of heat is utilised with a much saving of fuel.

Steel produced by this process is much milder than the steel obtained by the Bessemer process. In the Open-hearth process the percentage of carbon which varies prom ·1 to ·5 per cent can easily be adjusted to suit the classes of work. Engineers prefer Open-hearth steel (mild steel or ingot iron) to Bessemer steel for structural purposes as it is more homogeneous and reliable than Bessemer steel.

The Basic Bessemer process is also known as Thomas Gilchrist process.

Pig iron with high phosphorus content, as high as upto 2%, is suitable for the process. The steel is manufactured in two stages. Iron, manganese and silicon are oxidised and from basic slag with lime in the first stage. In the second stage, the carbon content is reduced to ·2 per cent and the temperature of the furnace is brought down to ·2 per cent. In the third and final stage phosphorus is oxidised and forms slag.

$$2P + 5FeO + 4CaO = (CaO)_4 P_2O_5 + 5Fe.$$

The slag is suitable as a fertiliser and contains 22% of $P_2O_5$.

5.10.5. *Electric Smelting*. By this process steel is manufactured from ore mixed with necessary amount of reducing agent. Electric process has many advantages in metallurgical operations of small-scale for its control, readiness of transit, absence of ash and smoke and the wide range of possible temperature. Electric furnace (Fig. 5·6) is about 7·5 m high and not suitable for manufacture of large quantities of ordinary material but usefully employed to supplement the work of the Open-hearth furnace and Bessemer converter to produce a small quantity of special steel and iron alloys.

The ore mixed up with proportionate reducing agent and suitable flux is run into the electric furnace from the top and an arc is struck between the two electrodes E, E of the furnace and the mixture gradually melts in the melting chamber or hearth H. As steel collects it is tapped at intervals. Electricity is only used as a source of heat but purification has nothing to do with electricity and it takes place as in Bessemer and Open-hearth processes. Electric furnace is practically a closed basic Open-hearth furnace where temperature is much higher.

Electric smelting is economical only where electricity is cheap and coke is dear.

5.10.6 *Duplex Process*. This is a combination of Acid Bessemer process and Basic Open-hearth process. The converter with silica lining eliminates silica, manganese and carbon from pig iron while basic Open-hearth removes sulphur, phosphorus, etc. from pig iron Thus it eliminates the various impurities in two stages. *Triplex Process* is recommended for high quality steel when Duplex steel is further refined in electric furnace.

5.10.7 *L. D. Process*. In this latest process adopted at Rourkela (Orissa), a jet of oxygen from an oxygen plant is blown at supersonic speed on to the molten bath of hot metal of L.D. converter. The impurities are burned due to the high temperature developed and thereby leaving in the converter a pure low carbon steel. Each converter produces about 40 tons or tonnes of steel within 40 minutes. This process is economical both in capital and running cost but the temperature cannot be thoroughly regulated as in open hearth process.

## 5.11 Classification of steel

The principal varieties of steel are as follows :

1. *Blister steel* is obtained by adding carbon to wrought iron by the cementation process. It is full of fissures and cavities. It cannot be forged but can be welded. It is used for conversion into other descriptions of steel, facing hammers and steeling masons' points but not for edge tools.

*Spring steel* is blister steel heated to red colour and rolled or hammered. It may be alloyed with small proportion of carbon, chromium, silicon, manganese and tungsten.

2. *Shear steel* or *tilted steel*. By cementation process the exterior only of bars is carbonised. To obtain steel of uniform quality throughout its mass, bar of blister steel is cut into short lengths, tied together, sprinkled with sand and borax, placed at welding heat under tilt hammer, which by rapid blows removes blisters and amalgamates the bundle of bars into a bar of *single shear steel*. For further improvement in quality of metal the process of doubling, hammering and rolling are repeated, the result being a bar of *double shear steel*. It is used for knives, scythes, shears, cutting tools, etc.

3. *Cast steel*. In order to get rid of the cavities of blister steel and shear steel, these are reheated at low temperature and hammered into bars and thereby these are made compact and homogeneous. Cast steel is the strongest and the most uniform steel prepared. It is used for high grade instruments.

*Crucible cast steel* is obtained by melting fragments of blister steel in covered fireclay crucibles. Cast steel is used for finest cutlery and hardest cutting tools.

4. *Whitworth compressed steel* is obtained when molten steel is subjected to a pressure of 9 kg/mm$^2$ and thereby gases expelled, cavities closed up and strength greatly increased. It is used for rivets, boring tools, boilers, guns, parts of machines, etc.

5. *Bessemer steel* is obtained from Bessemer pig in a converter. It is used largely for rails, axles, tyres for railway carriage wheels, and also for common tools, cutlery, boiler plates, etc.

6. *Mild steel* is obtained by Open-hearth process. It is now most generally used for structural purposes, such as, roofs, bridges, joists, girders, railway materials, ship buildings, etc.

7. *Electric furnace steel* is obtained by the heat of electricity. These are high grade steel, special steel and steel alloys.

### 5.12 Modern alloy steel or hard steel

It is made by adding a small percentage of metals, such as, nickel, manganese, chromium, tungsten, vanadium, titanium, carbon, etc. to liquid steel immediately before pouring into moulds in order to give in each case greater hardness, toughness, elasticity or durability. Generally when steel is hard and strong it is correspondingly brittle and so liable to crack but manganese and nickel steels are exceptions. These are very hard and strong but very ductile as well. The principal alloy steels are :

1. *Nickel steel* is very strong, hard and ductile. It is used in shaftings, axles, bearings, long span bridge, armour of war vessels, guns, naval purposes, etc.

2. *Manganese steel* is very durable, hard and ductile. It is used for ails under heavy traffic and on sharp curves, rollers, safes, railway switches and crossings, car wheels, dredger buckets, jaws of rock cutting machine, etc.

3. *Chrome steel* is very hard, of much strength and of moderate toughness. It is used for blades, chisels, files, bearing balls and rollers, rails, etc.

4. *Tungsten steel* is very hard. It is used in magnets, rails, cutting tools, etc.

5. *Chrome nickel steel* is of much strength, hardness, elasticity and toughness combined with ductility. It is used for rock cutting machinery, armour plating, gear axles, shafts, safes, etc.

6. *Vanadium steel* is of much strength, and hardness, and resists shocks. It is used for axles, springs, forgings, engine frames, etc.

7. *Chrome-tungsten or high speed steel* is very hard and has cutting power at high speed. It is used for lathe tools and other cutting tools.

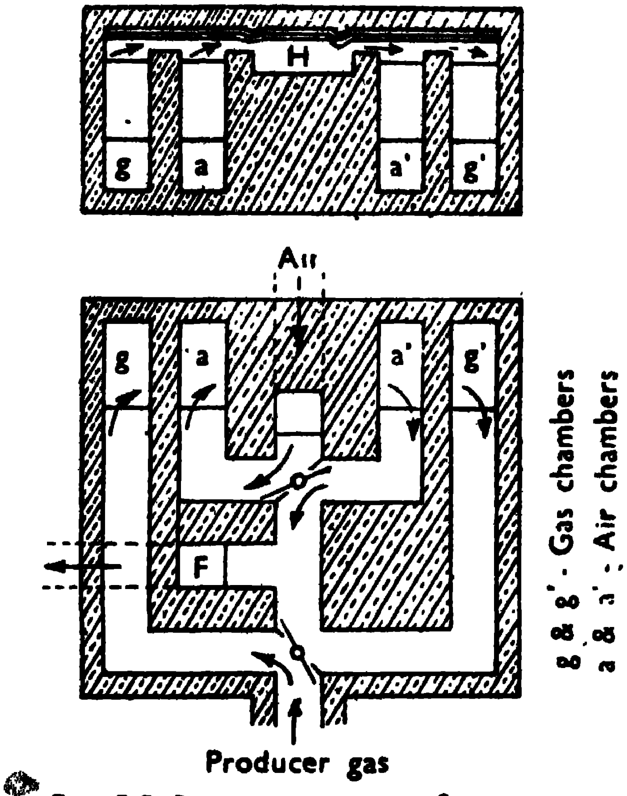


Fig. 5.5 Regenerative gas furnace

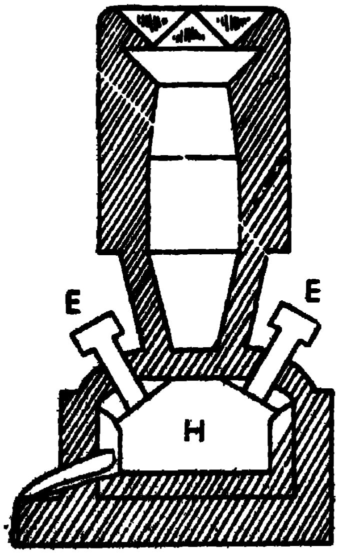
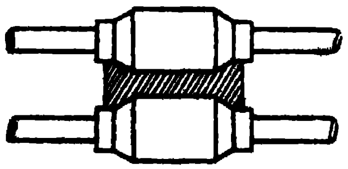
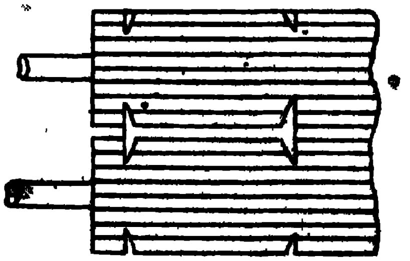


Fig. 5.6 Electric furnace



Rollers for rough sections



Rollers for finished sections

5.7 Rolling

8. *Titanium steel* is of very high tensile strength and is homogeneous. It is used for steel rails.

9. *Carbon steel* is hard and elastic. It is medium carbon steel or high carbon (tool) steel. It is used for boiler, ship plates, bridges, rails, tyres, guns, armour plates, tools, etc.

10. *Invar* contains 36% of nickel and has low coefficient of expansion. It is used for parts of surveying instruments, levelling staff, clock pendulums, etc.

11. *Stainless steel* is an alloy containing 18% of chromium and 8% of nickel, and resistant to acids, salts and alkalies. It is used for cutlery and surgical instruments.

12. *Silicon steel* contains 1 to 2% silicon. It imparts hardness and strength.

13. *Tool steel* contains 0·7 to 1% carbon and it maintains its hardness even at high temperatures.

14. *Molybdenum steel* contains small quantity of chromium and manganese. It maintains goods tensile strength at high temperatures.

15. *Cobalt steel.* Addition of 35% cobalt to hign carbon steel makes a permanent magnet

16. *High speed steel* contains 18% tungsten, 4% chromium, 1% vanadium and 0·6% carbon. It retains its hardness at high temperature.

17. *Clad steel* is a composite plate made up of steel plates with a veneer or cladding of a metal or alloy on one or both faces for resisting corrosion, heat or both.

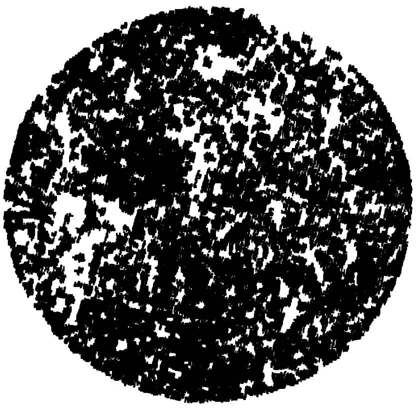
### 5.13 Defects in steel ingots and other steel castings

1. *Piping* is formed due to the cooling of the outer layer faster than the inner ones when molten steel ingot is cast in a cold iron mould.

2. *Blowholes* are formed when gas is confined in the solidifying metal producing gas bubbles or blowholes. This is prevented by adding either silicon or aluminium or both to the molten metal just before it solidifies.

3. *Segregation* is the concentration of impurities in molten steel ingot to the last freezing part of the ingot, due to the expulsion of impurities during gradual solidification of molten ingot from outside to inside.

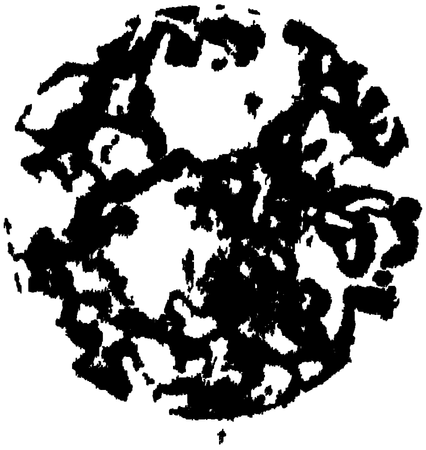
(a) Ferrite



(d) Sorbite

(b) Pearlite & Cementite

(e) Martensite



(c) Troostite

Fig 5 8 Microstructure of Constituents of Steel

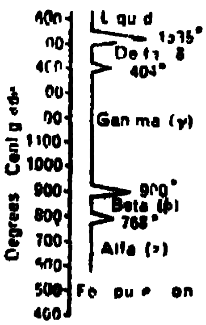


Fig 5 9
Cooling curve for pure iron

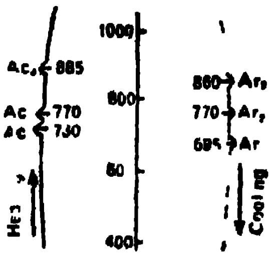


Fig 5 10

Heating & Cooling Curves for Steel

### 5.14 Rolling, forging and drawing (Fig. 5.7)

The principal processes for shaping steel are *rolling*, *forging* i.e. hammering or pressing, and *drawing*. The metal is squeezed into the required shape by one of these processes. In *rolling* the metal between two adjustable parallel cylindrical rollers (plain or grooved), turning about their axes in opposite directions, is drawn forward by the friction of the revolving rollers and reduced in section but lengthened proportionately by its first pass. It may be given a second or third reduction. In *forging* under hammer or press, the action is a squeeze. Forging metal is done by raising temperature and then hammering or squeezing. In *drawing* the metal is reduced in diameter and lengthened proportionately in the die.

### 5.15 Heat treatment of steel

1. Cooling Curves :

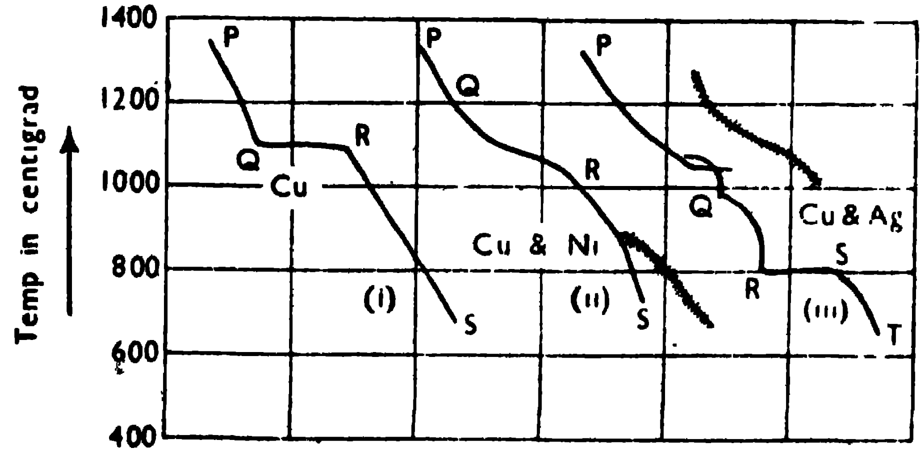


Fig. 5.11 Typical cooling curve

During the process of manufacture most of the metals have to undergo heating to a temperature which is well above their melting point and subsequent cooling of the same. The method of heating and cooling play a very significant role in the properties of the finished material.

Curve (i) shows the cooling of copper. Cooling from P to Q is gradual while for Q to R solidification takes place in such a way that the evolution of heat is so maintained that the temperature remains constant. The phenomenon may be compared to the change of liquid water at 0°C to ice at 0°C though there is considerable liberation of heat.

Curve (ii) represents the solidification of liquid metal solution of two metals. From P to Q cooling is regular. At point Q the solidification of a solid solution of two metals dissolved in each other. With the lowering of temperature and lapse of time, temperature drops till point R is reached. The solution solidifies along the line RS.

Curve (iii) represents cooling of (Cu and Ag), two metals that dissolve in each other while liquids but while solids, they do not remain dissolve. Along the region PQ, the mass is liquid, from Q to S it is partly solid and partly liquid while in the range ST it is completely solid.

### 5.16 Allotrophic forms of iron

From the cooling curve for molten *pure iron* drawn against time, it is found that the temperature is steady for a while at 4 different fixed points known as *arrest points* or *critical temperatures* as marked in Fig. 5·9. Below 768°C the iron is *alpha-iron*, that between 768°C and 900°C is *beta-iron*, that between 900°C and 1404°C is *gamma-iron*, and that between 1404°C and melting point 1535°C is *delta iron.*

*Alpha-iron* (ferrite) has high magnetic permeability. All its atoms are arranged in cubes. *Beta-iron* is like alpha iron but it is non-magnetic. *Gamma-iron* is also non-magnetic and has 14 atoms in all. *Delta-iron* is also ferrite and its structure is like *alpha-iron.*

### 5.17 Arrest points for steel

The heating and cooling curves for steel with 0·20% carbon are shown in Fig. 5.10. The *arrest point* (A point) on heating curve is marked as Ac and that on the cooling curve is marked as Ar. The arrest points during cooling are lower than corresponding points during heating. *Thermal lag* is the difference in temperature between an arrest point on cooling curve and the corresponding arrest point on heating curve and it depends on the % of carbon and also on the rates of heating and cooling. At $Ac_1$ *pearlite* changes into *austensite.* At $Ar_1$ *austensite* changes into *pearlite.* At $Ac_2$ steel looses magnetic properties but these properties are regained in steel at $Ar_2$. At $Ac_3$ austensite solid solution is completed but at $Ar_3$ precipitation of cementic commences during cooling. The gap between the arrest points are reduced when the carbon content of steel increases. When carbon content is 0·85%, $Ar_1$, $Ar_2$ and $Ar_3$ points coincide at 695°C and $Ac_1$, $Ac_2$ and $Ac_3$ points coincide at 730°C giving a thermal lag of 35°C.

### 5.18 Crystal structure and metallography of iron and steel

*Metallography* is a study of the crystalline structure of a metal or alloy under a microscope. The freshly fractured surface of a specimen of iron and steel shows clearly the presence of crystals of different shapes and sizes under the microscope. The sizes of crystals vary widely depending on the rate of cooling during solidification. The magnified structure seen through a microscope is called ***microstructure*** (crystalline structure). Fig. 5.8 ***Ferrite, pearlite, cementite, austensite, troostite, sorbtite*** and ***martensite*** are the different crystalline forms of the constituents of iron and steel. ***BHN is Brinell Hardness Number.***

*Ferrite* (*alpha iron*) is the toughest and most malleable and ductile iron with highest electrical conductivity and magnetic permeability. BHN-90.

*Cementite* ($Fe_3C$) is the hardest constituent of steel. It scratches glass and is very brittle. BHN-650.

*Pearlite* is a conglomerate of ferrite and cementite due to slow cooling of steel. BHN-300.

*Austensite* is the solid solution of $Fe_3C$ in *gamma iron.* Its cutting hardness is far less than its resistance to wear. It is tough and non-magnetic.

*Martensite* contains iron both *alpha* and *gamma* forms. It is next in hardness and brittleness to cementite. It is formed by transformation from austensite on rapid cooling to 200°C. It retains its hardness unless warmed but it is not homogeneous.

*Troostite* is obtained from martensite by heating to 400°C. It is less brittle and less hard than martensite.

*Sorbite* is obtained when quenched steel is heated to 400°C. It is stronger and tougher than pearlite.

## 5.19 Temperature effects on mechanical properties of steel

The elasticity, ductility and tenacity of the important metals do not vary seriously within the limits of atmospheric temperature but it is found by experiments that the strength of metals is reduced at a high temperature. The following effects are observed by experiments in case of mild steel and wrought iron :

(1) The elastic limit falls gradually as temperature rises.

(2) The alongation falls with the rise of temperature upto about 300°F and then increases gradually with the rise of temperature but it practically vanishes at very low temperature.

(3) The modulus of elasticitv decreases continuously with the rise of temperature.

(4) The tenacity falls gradually with rise of temperature until between 200° and 300°F approximately, then it rises continuously with rise of temperature until between 400° and 600°F approximately, but it falls again with further rise of temperature. At very low temperature it is found that tenacity increases with decrease of temperature. Original properties however are again observed on return to ordinary temperature.

## 5.20 Fatigue of metals

It is found by experiment that constructional metals, such as, steel, W.I., etc. ultimately fracture by loads very much lower than their ultimate static load when they are either subjected to fluctuating or reverse stresses. In these cases it is often said that the metal is fatigued. The following important deductions may be obtained from experiments :

(1) The resistance to fracture under fluctuating stresses depends more on the algebraic difference between max. and min. stresses than upon max. stress applied.

(2) The reverse stresses even well within elastic limit will cause fracture if repeated.

(3) There is a limiting range of stress called fatigue range within which unlimited repetitions will not cause fracture of the materials.

(4) Many factors, such as, shape, nature of surface finish of test piece, heat treatment and temperature of test will effect the fatigue of metals.

## 5.21 Heat treatment of steel

It is an operation involving the heating and cooling of a metal in the solid state for inducing in it certain physical properties and structural changes.

1. *Forging* : It means shaping iron or steel with hammer when it is softened by heat.

2. *Welding* : It means jointing pieces of iron or steel together under hammer when they are almost molten or white hot. Other methods of welding are oxy-acetylene welding and electric welding.

3. *Hardening* : Red hot steel when plunged into cold water becomes very hard. This process of hardening makes the steel very brittle and so it must be tempered for its toughness before use.

4. *Tempering* : The process of tempering or softening depends upon another characteristic of steel. The hardness of hardened steel diminishes as the heat increases by reheating. In order to obtain steel of a certain degree of toughness the hardened steel is gradually reheated in a moderate temperature and then allowed to cool to a certain temperature which experience has shown will produce the limited degree of hardness. It is of much importance in the manufacture of spring, cutting tools, etc.

5. *Annealing* : Steel is effected by raising the hardened steel to red heat and then allowing it to cool gradually inside the furnace. It regains its original softness by this process.

6. *Normalising* : It is similar to annealing but involves quicker cooling. It gives refined product with improved elastic properties.

7. *Softening* : It consists heating steel to below lower critical point and allowing it to cool slowly. This removes the internal strains of steel due to fabrication.

8. *Case hardening* or *carburising* : It is a process by which the surface of wrought iron is turned into steel, so that a hard exterior, to resist wear and tear, is combined with the toughness of the iron in the interior. The article to be case hardened is placed in an iron box full of bone dust or some other animal matter and subjected to a red heat for a period depending upon the depth of steel required. The iron at the surface combines with a little carbon and is turned into steel to a depth varying from $\frac{1}{16}$ to $\frac{3}{8}$ of an inch or 2 to 10 mm in a period varying from $\frac{1}{2}$ to 8 hours.

9. *Austempering* is done by heating steel above critical range 746°C, cooling it in a bath of molten salt or lead at 316°C and then cooling it in air. Thereby the steel is rendered ***shock resisting***.

10. *Patenting* is applied to high-carbon steel wires by heating above the critical range and then cooling those in molten salt or lead so as to render them ductile and suitable for further drawing.

11. *Quenching* : The structural changes caused during heating of the metal can be permanently set by plunging heated metal into a bath of water or oil and cooling it quickly. This operation is known as quenching.

12. *Martempering* : The steel piece to be hardened is heated above the critical temperature and then quenched in a molten salt bath whose temperature is slightly above that at which martensite forms. By this process, which is known as martempering in addition to getting hardened, toughner and ductility of steel is improved and the internal stresses and distortion are reduced.

## 5.22 Iron-carbon constitutional diagram

Iron with any other combination above the line PQR known as Liqui Dus will always be in a liquid state. It will be seen that with the increase of percentage upto 4.3%, the melting point goes on decreasing. The line PSQT below which the alloy remain solid is known as "Soli Dus". In the intermediate portion, the alloy remains in equilibrium partly in liquid state and partly in the state of solid crystals.

All alloys of iron and carbon, in which the percentage of iron is below 1·7% are called steel and these containing above 1·7% are called cast iron. Iron-carbon alloys beyond 5 p.c. of carbon have no practical importance.

*Euctectoid reacter* : A state of being in which a solid metal splits itself into two solid phases. The transformation of one-phase liquid solution into two solid phases is also known as "Euctectoid" reactor.

*Euctectic temperature* : At 1130°C Iron-carbon alloy containing 4·3% carbon is completely solidified and this temperature is known as "Euctic" temperature. It is further noticed that if the percentage of carbon is ·83%, solidification takes place at 723°C and the corresponding point V is known as "Euctectoid".

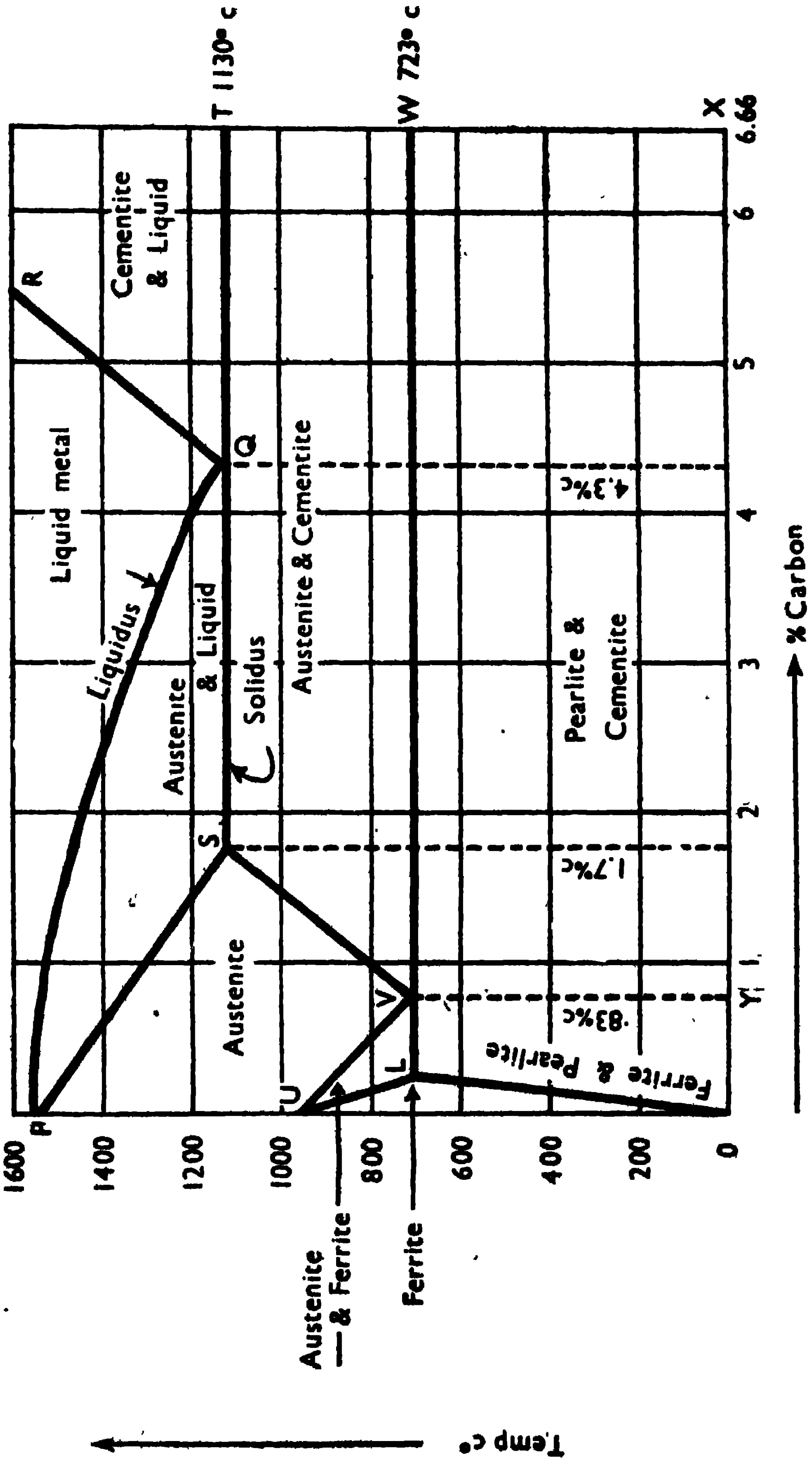


Fig. 5.12 Iron Carbon constitutional diagram

## 5.23 Effects of impurities in iron

The impurities in iron are carbon, silicon, sulphur, phosphorus and manganese. Except carbon other impurities are in small quantity. Cast iron, wrought iron and steel are produced from the same ore and the percentage of iron in them is practically the same but they differ very widely in their mechanical properties and characteristics. The great differences that exist between them depend chiefly upon the amount of carbon they respectively contain. Cast iron contains carbon about 1·5 to 5·5%, steel contains carbon about ·05 to 1·75% and wrought iron contains carbon about ·25%.

*Carbon* makes wrought iron hard and brittle, and steel brittle and unforgeable.

*Silicon* resembles carbon in its action.

*Sulphur* tends to produce white varieties in cast iron, over ·3% in wrought iron produces red shortness, and over ·2% in steel renders it unfit for forging but makes it better for casting.

*Phosphorus* makes cast iron more easily fusible but weakened, ·1% in wrought iron improves the welding qualities but more makes it cold short and the smallest quantity to steel makes it cold short.

*Manganese* produces white varieties of cast iron and counteracts red shortness in wrought iron and steel.

## 5.24 Market forms of steel and wrought iron

Steel and wrought iron are prepared for the market in variety of convenient forms.

*Bar iron* (round, square or flat) is manufactured up to 10 m in length. Available from 6 mm to 76 mm diameter in increments of 2 mm.

*Round* or *square bars* are usually 12 mm to 7·5 cm in diameter or sides increasing by 2 mm. Round ones are known as *rods* and *wires* if under 2·5 cm and 5 mm diameter respectively.

*Flat bars* are usually 2·5 cm × 6 mm to 30 cm × 2·5 cm, width increases 3 mm and thickness by 2 mm.

*Angles* may be up to 13·5 m in length and sections vary from 3 cm × 3 cm × 6 mm to 23 cm × 23 cm × 5 mm. There are *equal* or *unequal angles* according as their sides are equal or otherwise.

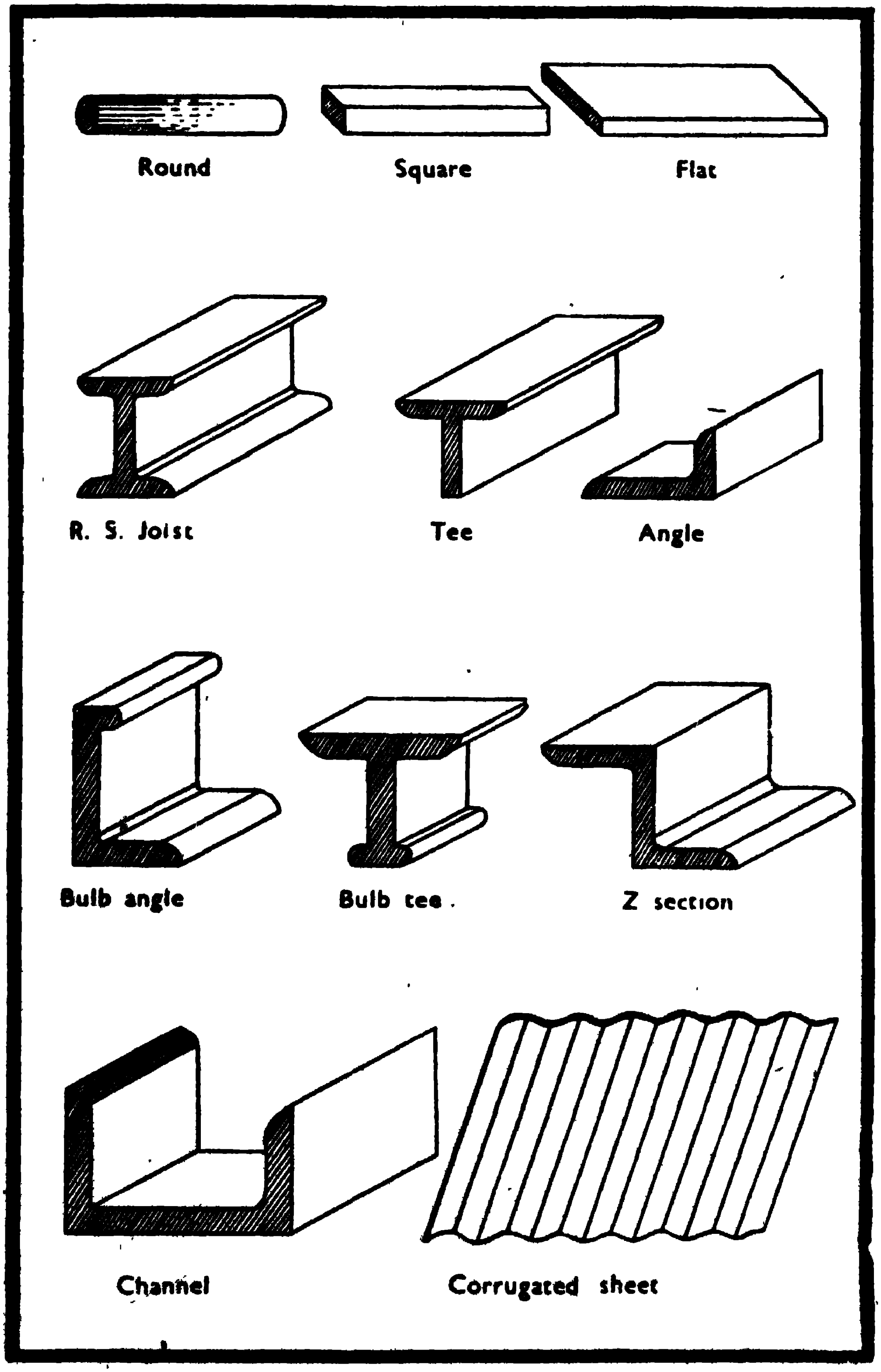

Round
Square
Flat
R. S. Joist
Tee
Angle
Bulb angle
Bulb tee
Z section
Channel
Corrugated sheet

Fig. 5.13

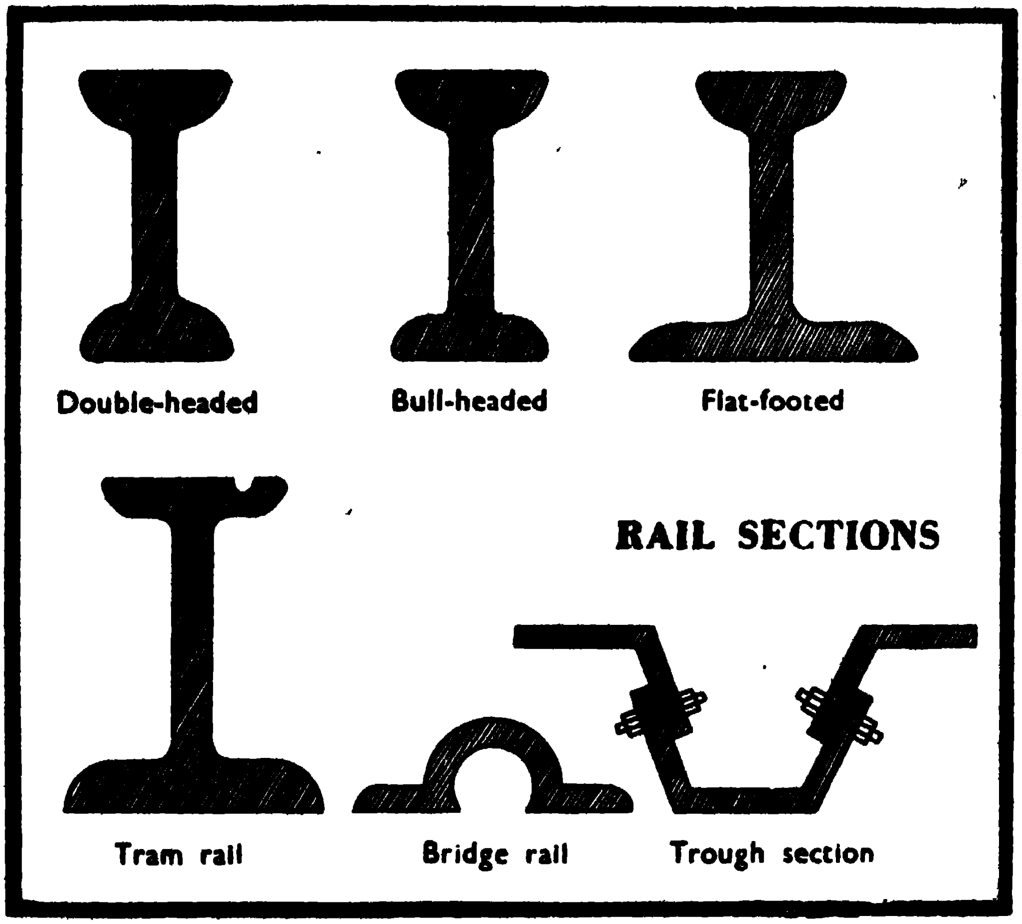


Fig. 5.13 (*contd.*).

*Tees* may be up to 12 m in length and sections vary from 4 cm × 4 cm × 6 mm to 15 cm × 15 cm × 15 mm. There are *equal* and *unequal tees* like angles.

*Channels* may be up to 10 cm in length and sections varying from 10 cm × 6 cm to 40 cm × 10 cm are used in built-up beams and girders.

*Rolled joists*, *I-sections*, or *girders* in a great variety of sections are kept by different manufacturers. These are used as beams and columns, in bridges and other structural works.

*Bulb angles* and *bulb tees* are used mostly in ship building.

*Z-sections* are used in steel trusses.

*Rail bars* may be flat footed, double headed or bull headed. Flat footed rails are used for light traffic, double headed rails are no longer in use and bull headed rails with cast iron chairs are now-a-days mostly used for heavy traffic. *Tram rails* are different from ordinary rails usually laid flush with street level. *Bridge rails* were used in Rlys. Weight of rail is expressed in (kg/m).

*Plates* vary from 3 mm to 2.5 cm in thickness.

*Sheets* are generally made in thickness of 2 mm and 3 mm (less than 6 mm). The thickness is expressed by B. W.G. (Birmingham Wire Gauge) or S. W. G. (Standard Wire Gauge) numbers.

*Corrugated sheet iron* is made by passing plain sheets between grooved rollers which bend them into parallel waves or corrugations. The strength and stiffness of sheets are considerably increased due to corrugations. These are about 75 cm wide but length varies from 2 m to 3 m. Both plain and corrugated sheets are generally galvanised (coated with zinc) to protect iron from corrosion by rust. Corrugated sheets are used in slant roof but plain sheets are used in partitions.

*Hoop irons* are narrow thin sheets 1·25 cm wide used largely in reinforced brick-work and packing cases.

*Troughs* are used for bridge floors.

*Nails* (Fig. 7·4) are either hand wrought or machine cut. There are many varieties of nails named from the forms of their heads and points or from the nature of their use. These are used mostly for fixing wood works.

*Screws* (Fig. 7·5) are used for screwing into wood instead of nails in important works.

*Bolts* and *Nuts* (Fig. 7·6) are used when wood screws would not offer enough tensile resistance. These are used in carpentry for heavy work and in connection with iron roofs. Bolts are held in position by a head at one end and a nut screwed on at the other end in the case of wood work, a washer being placed at each end. When the thread is cut into the bolt or rod it is called *minus thread* and the bolt is weakened thereby. When the end of the bolt or rod is thickened by upsetting and the thread is cut so as not to reduce the effective diameter of bolt then it is called *plus thread.* The thread on the bolt is called the *male thread* and that in its nut, into which it fits, is called the *female thread.*

*Rivets* (Fig. 7·7) are used to secure iron plates together. Rivet holes are either punched or drilled but the latter ones are better. They are put in while hot and hammered up from other ends. Riveting is done either by hand or machine. There are two kinds of joints. When one plate overlaps the other and riveted together, it is called a *lap joint* but when one plate comes flush with the other and riveted with cover plates on one or both sides it is called *butt joint. Pitch* is the distance from centre to centre of rivet holes. Generally *minimum pitch* is three times the diameter of rivet and *maximum pitch* is sixteen times the thickness of the thinner plate so that joints may not fail. Usually sizes of rivets to correspond with thickness of plates are as follows :

| Thickness of plates | Diameter of rivets |
|---|---|
| 6 mm to 10 mm | 9 mm |
| 12 mm to 15 mm | 18 mm |
| 15 mm to 25 mm | 21 mm |

*Expanded metal* (Fig. 7·8) is manufactured from steel sheets or plates by piercing them with parallel rows of slits and then stretching open the gashes until metal assumes the form in various sizes of mesh. It is largely used for reinforced concrete (R. C.) in roads, walls, roofs, lintels, tanks, and pipes ; as lathing for plaster in ceiling and encasing steel work for fenches, open partitions and guards for windows, trees, etc. Brass and copper expanded metal sheets are also manufactured.

*N.B.* : The different types of nails, screws, bolts and rivets are shown in figures 7.4, 7.5. 7.6, 7.7 :

The size of expanded metal is based on the following features :

(i) Size of mesh : It is measured in term of SWM (short way mesh) and LWM (long way mesh) as shown in Fig. 5·14.

(ii) Width and thickness as shown :

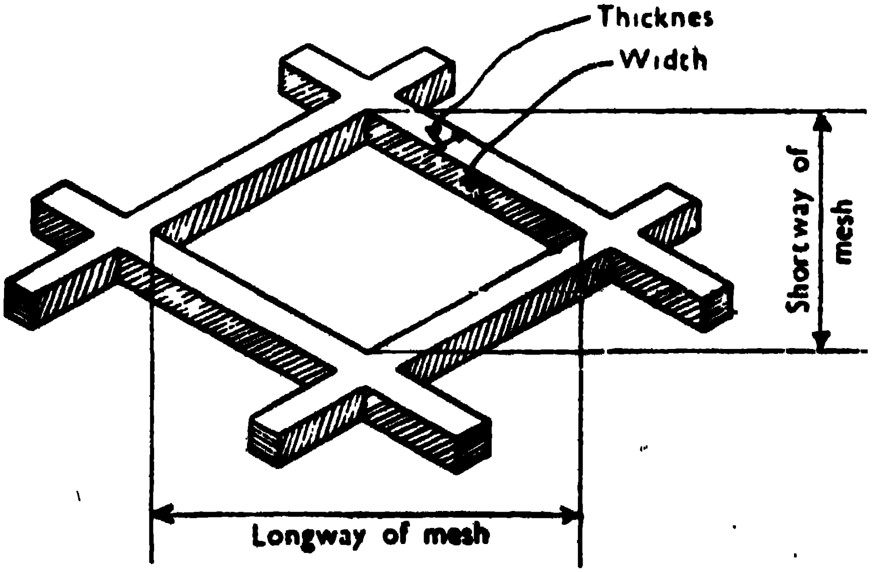


Fig. 5.14. Expanded metal.

The limits of properties and dimensions of Expanded Metal are as given below :

Size of Mesh : SWM and LWM from 20 mm × 50 m to 25 mm × 75 mm.

Width : 2·5 mm to 3·5 mm.

Thickness : 1·25 mm to 3·15 m.

Normal weight per 2·285 kg/sq.m to 6·050 kg/sq.m.

Size of sheet 1 mm × 3 m to 2 mm × 3 m.

## 5.25 Cast iron, wrought iron and steel compared

| Points of comparison | Cast iron C. I. | Wrought iron W. I. | Steel Mild steel—M.S. Hard steel—H.S. |
|---|---|---|---|
| Composition | Impure iron, carbon 2 to 5%. | Purest iron, carbon 0 to ·25%. | Carbon in M. S. ·1 to ·5%, in H. S. ·5 to 1·5% |
| Structures | Crystalline and coarse granular. | Fibrous structure. | M.S.-fibrous structure.<br>M.S.-granular structure. |
| Physical properties or qualities with reference to fusibility, hardness, toughness flexibility, etc. | (1) Melts readily.<br>(2) Hard and brittle, scarcely bend at all.<br>(3) Hardened by heating and sudden cooling but cannot be tempered.<br>(4) Cannot be forged nor welded.<br>(5) Cannot be magnetised.<br>(6) Does not rust easily.<br>(7) Becomes soft in salt water. | (1) Does not melt.<br>(2) Tougher and more elastic than C. I.<br>(3) Very malleable and ductile cannot be hardened or tempered.<br>(4) Can be forged and welded easily.<br>(5) Temporarily magnetised.<br>(6) Rust more rapidly.<br>(7) Stands salt water better. | (1) Can be melted according to qualities.<br>(2) M.S. is tougher and more elastic than W.I.<br>(3) M.S. malleable and ductile, hardened & tempered not so easily. H.S. readily hardened & tempered.<br>(4) M.S. readily forged and welded, but H.S. not easily forged and welded.<br>(5) Permanently magnetised.<br>(6) Rusts very rapidly.<br>(7) Not much effected by salt water. |
| Weight | 7·25 tonnes/$m^3$ | 7·70 tonnes/$m^3$ | 8 tonnes/$m^3$. |
| Tension | 14 kg/$mm^2$ | 30 to 40 kg/$mm^2$ | M.S.—60 to 80 kg/$mm^2$.<br>H.S:—90 kg/$mm^2$. |
| Compression | $48^T$/sq. in. | 16 to $20^T$/sq. in. | M.S.—80 to 120 kg/$mm^2$.<br>H.S.—140 kg/$mm^2$ |
| Shear | Very weak. | $20^T$/sq. in. | M.S.—60 to 80 kg/$mm^2$<br>H.S.—110 kg/$mm^2$ |
| Factor of safety | 6 to 10 | 4 | 4 |
| Use | Used for columns, struts, bed plates, rail chairs, carriage wheels, parts of machinery and other structure subjected to compression. Used also for water pipes, gutters, railings, gates and other ornamental works. Never used as tension member. | Used for small sized water pipes and fittings, corrugated sheets, wires, ornamental works and also used for conversion into hard steel. Now-a-days not much used in structural works being almost entirely suspended by mild steel. | M. S. is used for all kinds of structural works in beams, joists, girders, channels, tees, angles, plates, bars, bolts, rivets, wires, etc.<br>H.S. used for cutlery and structure where a hard, tough and elastic material is necessary. It is best suited to stand shocks and vibrations, also wear and tear. |

## 5.26 Stress-strain curves (Fig. 5·15)

Bars of mild steel (M.S.), wrought iron (W. I.), and cast iron (C.I.), are tested in tension by applying a gradually increasing load till rupture occurs. Graphical representation of the phenomenon of tensile test is called tensile stress-strain diagram. There are two distinct types of diagrams : (a) diagrams for most wrought metals, such as, W. I. and M. S. and (b) that of C.I.

In type (a) the following points may be noted in M. S. :

1. There are 3 phases of tests : elastic, ductile—partly elastic and partly plastic, and plastic.

2. Up to point A metal is practically elastic. Stress at A is elastic limit.

3. At B metal stretches rapidly under constant load. Stress at B is yield.

4. Then the metal recovers to some extent and continues to stretch as stress rises. Stress at C is ultimate stress.

5. After point C metal enters plastic phase and extends under decreasing load till rupture occurs at D. Stress at D is breaking stress.

In type (b) the following points may be noted in C. I. :

1. There is no well defined elastic limit or yield point.
2. Metal breaks off short.
3. It has no ductile or plastic phase.
4. Stress-strain curve is almost straight.

## 5.27 Corrosion and rusting of iron and its preservation

The corrosion of iron goes on entirely from outside and is chiefly due to oxidation. Rust is the formation of oxides on the surface of iron. Cast iron oxidises less, steel oxidises most, and wrought iron is intermediate. The different varieties of iron will rust when exposed to the action of water or moisture and air alternately, but will not rust in dry air nor when totally immersed in water

Rusting of iron is due to the combined action of oxygen, moisture and carbon-dioxide converting the metal first to a soluble ferrous

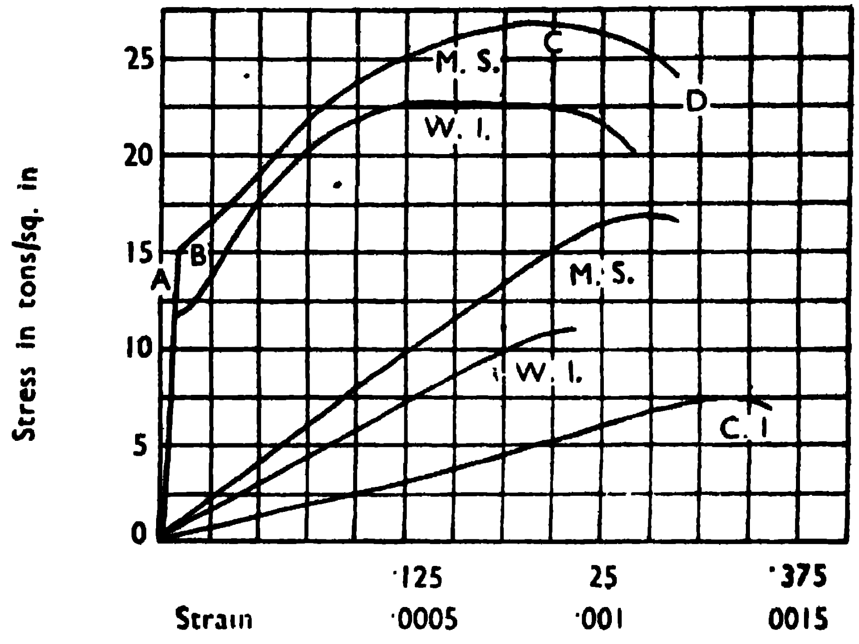


Fig. 5 15 Stress strain curves

bicarbonate. It is next oxidised to a basic ferric carbonate and finally to a hydrated ferric oxide with liberation of carbon-dioxide as shown below :

$$Fe+O+H_2O+2CO_2 = Fe(HCO_3)_2$$

*Ferrous bicarbonate*

$$2Fe(HCO_3)_2+O = 2Fe(OH)CO_3+H_2O+2CO_2$$

*Basic ferric carbonate*

$$Fe(OH)CO_3+H_2O = Fe(OH)_3+CO_2$$

*Hydrated ferric oxide*

The usual methods of preservation are 1. *galvanising*, 2. *Tin plating*, 3. *Enamelling*, 4. *Painting*, and 5. *Coal tarring*.

1. *Galvanising* consists in covering iron with a thin coat of zinc. For galvanising, iron is first cleaned perfectly by steeping in a weak solution of sulphuric acid and washing, and then heated and plunged in a bath of molten zinc. The zinc protects the iron from oxidation so long as the coating is entire. When the galvanized surface gets chipped or damaged, a galvanic action is set up by iron rusting and destroys iron. Plain and corrugated sheets and their fittings are mostly galvanized. 2. *Tin plating* consists in covering iron with a thin coat of tin, instead of zinc in galvanizing, by immersing thoroughly cleaned iron sheets in a bath of molten tin. The coating of tin is perfected by passing plates through successive tin baths. The plates are finished off

by passing through rollers in a grease bath to squeeze off the excess of tin. 3. *Enamelling* consists in putting glaze to the iron by melting a suitable flux on it, when iron is thoroughly cleaned from grease and rust by scouring. It is used as a protection and also ornamentation of iron specially for domestic utensils, sign boards, etc. 4. *Painting* is a very good method of preserving iron from oxidation if the paint is a good one and properly applied on the properly cleaned surfaces of iron. It is the effectual and only method for the preservation of structures already erected. Painting is described thoroughly in Chapter VI. 5. *Coal tarring* laid hot acts as a good preservative and is generally employed on iron and timber below ground and where appearance is of little importance.

The other useful methods are as follows :

*Electroplating*—Metallic coatings on iron can be given on the principle of electrolysis. If an electric current passes through a solution between two electrodes then the solution breaks up into ions which deposit on the cathode. Iron to be electroplated is made the cathode and the anode is a piece of pure metal of which the coating or plating is to be made. The metal for the protective coating are chromium, nickel and zinc.

*Nickel-plating*—Brass and copper articles are first copper plated and then immersed in a bath of a cyanide and other metals in one of dilute sulphuric acid.

*Chromium-plating*—The articles are first nickel-plated otherwise chromium plating does not give a good finish.

*Sherardising* consists in covering the cleaned articles with dust of pure zinc and are packed in air-tight steel boxes, which are heated in a furnace under controlled temperature. The zinc melts and combines with the metal to form an alloy which covers the entire surface. It can be removed only by filing or grinding.

*Parkersing* consists in immersing the articles for an hour in a hot water bath of a chemical 'Parco' in the form of a powder. Insoluble phosphates are formed on the surface of iron by chemical reaction and it is stained grey and black.

*Perne-plating* coats iron in a bath of lead and tin. Lead with tin makes a good soldering material.

*Metal spraying* supersedes other methods on account of its simplicity and thoroughness. There are two types. In one, a wire and in the other, powder of the coating metal is used. The equipment consists of a 'pistol', a spool of wire of spraying metal, compressed air, oxygen, and a suitable fuel-gas. An oxy-hydrogen flame is produced inside the nozel, the metal wire in the zone is melted and the compressed air forces the molten metal in a fine spray through the nozzle automatically and thereby a film of uniform thickness is spread on the article.

*Plastic spray*—The suitable plastic used is of either urea resin or phenolic which can be spread in a hot liquid state by an ordinary spray gun.

*Fescol process* is based on electro-chemical deposition of either one or a combination of the following five metals : nickel, chromium, cadmium, lead or copper.

### 5.28 Alloys of steel

Plain carbon steel, with a maximum carbon content of 1·5% along with small percentages of silica, sulphur, phosphorus and manganese. Elements such as nickel, chromium and tungsten combine with plain carbon steel and form alloys. With the increase of carbon content from ·01% to 1·5% strengths and hardness of streel increases but such an increase beyond 1·5% causes appreciable reduction in the ductility and malleability of steel.

Low carbon steels or mild steel, containing carbon upto ·25% responds to heat treatment as far as improvement in the ductility is concerned but has no effect in respect of its strength properties. Medium carbon steels having carbon content between ·25% to ·7% improves in machinability by heat treatment. High carbon steel with carbon content from ·7% to 1·5% as a rule improve all-round due to heat treatment.

Mostly only one or two alloys are added to steel to make an alloy of the desired properties. The purpose of adding alloy material is to improve physical and mechanical properties of steel.

### 5.29 Principal alloys of steel

*Manganese* : Normally added in the form of ferro-manganese or silico-manganese, the % being between 1·65 and 2·10.

Manganese steel are non-magnetic have high electrical resistance and low coefficient of expansion. High manganese steel (10% to 14%) is very tough and hard and hence is useful for rock crushing and for use in railways.

*Nickel* : Addition of nickel, when the proportion of the alloy metal is below 3·5%, results in lowering the critical temperature range of steel for heat treatment. The danger of warping and scaling are reduced. Such a steel is extensively used for automobile and aircraft industry, forging, crankshaft, connecting rods and boiler plates. Higher proportions of metal improve strength and fatigue resistance appreciably. Invar, the steel alloy known for its property of having no appreciable expansion due to temperature effects, contain 36% nickel and 0·5% carbon. Such a steel can be turned, drawn, forged and rolled and is extensively used for precision work such as surveying and scientific instruments, pendulums for clocks and base line apparatus.

*Chromium* : The hardening and heat resistance of steel is improved by the addition of chromium. It is used for the manufacture of stainless steel when mixed with steel along with vanadium. Chromium upto 2% increases tensile strength of steel and is for cutlery, razors, permanent magnets crushing machines etc.

*Vanadium :* The yield strength and tensile strength of low carbon steel are improved by the addition of vanadium, upto ·25% addition is done in case of steel for constructional purposes while higher proportions are used, in combination with chromium for high speed tool steel, locomotives, crankshafts, spray steels etc.

*Tungsten* : For improving strength of steel at elevated temperature, tungsten has been found a very useful alloy. Cutting hardness and abrasion resistance property is thereby improved. For the manufacture of small generators, magnets and electrical instruments 3 to 6 per cent tungsten is alloyed with steel.

*Molybdenum* : To improve the hardening and cutting property of high speed steel and higher temperature steel is alloyed with molybdenum and tungsten.

Molybdenum also increases the hardness and tensile properties of steel and hence this alloy is used for gears, axles, shafts in automobiles and in aircraft industry.

*Free cutting steels* : Free cutting steels are manufactured in a number of ways to suit the specific requirement. The carbon content of such steels varies from 0·08 to ·45% and sulphur upto ·3%. The increase of sulphur content within reasonable limits improve the machinability of steel but to some extent reduces the cold working property of steel.

*Silicon* : When alloyed with steel upto 2·5%, silicon improves hardness of plan steel without reducing its ductility : such steel is largely used in the form of laminated cores for generators and transformers.

## 5.30 Stainless steel

Low carbon content steel or iron, with fairly high chromium content (over 12%) gives rise to the steel alloy known as "Stainless" steel on account of its corrosion resistance property.

When the chromium content is below 14% and carbon content below 0·4% and small quantities of tungsten, copper and nickel are used in addition, it results in a group of strainless steel which can be hardened by suitable heat treatment. Such alloyed steel is used for surgical instruments, scissors, gears, shafts, springs and ball bearings.

If the chromium content is between 16% to 20% and carbon content below ·45%, such an alloy is termed ferric stainless steel. Such an alloy is brittle and is not suitable for heat treatment but have better corrosion resistance qualities and can be rolled, forged, machined and welded. Such steel alloy is used for steels, wire, structural section and castings.

When the combined proportion of chromium and nickel is above 24% and neither of the two alloying constituents (chromium and nickel) is not below 8%, very tough steel results which can be welded, forged and rolled. Such an alloy is however difficult to be machined. Such stainless steel is used in the manufacture of hardware fittings, screws, nuts, bolts, pumpshafts and railroad car frames.

## 5.31 High strength steels

High strength steel, having corrosion resistant and erosion resistant properties is made from low carbon steel and suitable alloying metals. Such steel does not respond to quenching or tempering. Such alloyed steels are extensively used for the manufacture of scrapers, cranes, shovels conveyors and structural section.

*Spring steels* : In addition to the essential quality of ability to recover to the original shape after removal of the load, the springs should have resistance against shock, corrosion, fatigue and temperature effects : High carbon steel ·6 to 1% carbon, 1·5% Cr, ·2%V, alloyed steel, and 2%, Si, 1% Mn alloyed steels have been found satisfactory. The alloyed steel is heated to 860°C and quenched in oil path.

## 5.32 Non-ferrous metals

### 5.32.1 *Copper*

*Manufacture.* Copper is the most important metal next to iron used by Engineers. It is obtained from its ores which are oxides, sulphides and carbonates by dry, wet or electro-metallurgical process according to the nature of ores treated and local conditions. Its market forms are ingots, sheets, wires, and tubes.

*Properties*—It is a bright shining metal of reddish colour but on exposure colour changes into green being covered by a film of carbonate. It has a high tensile strength and is very malleable and ductile. It can be worked cold or hot but cannot be welded. It is a good conductor of heat and electricity. Its yield stress=6090 kg/cm$^2$, tensile strength=22400 kg/cm$^2$, Melting Point=1080°C, weight=8·8 gm/cm$^3$.

*Use*—It is used for electric cables and wires, lightning-conductors, bolts, nails, and locomotive fireboxes and tubes, dowels in stone masonry, making alloys, etc.

Copper form a self-protecting oxide films which prevents further corrosion of the metal even in polluted atmosphere in places near sea-shore. Copper is also used for damp proof course and for roof sheeting.

### 5.32.2 *Lead*

*Manufacture.* Lead is reduced from ores (sulphides or carbonates) by smelting in a reverberatory furnace. It is sold in sheets.

*Properties*—It is a bluish white heavy metal, very soft, plastic, malleable but wanting in tenacity and elasticity. Weight=11·35 gm/cm$^3$; Melting Point=327°C.

*Use*—It is used for roof covering gutters, cistern linings, gas pipes, water pipe joint fittings, making alloys and solders making white lead, printing types, as bedding for girder ends, etc.

Alloys of lead are used for making storage battery grids, bearing metals, solders etc. Pure lead is extensively used in the chemical processing industry.

### 5.32.3 *Zinc*

*Manufacture*—Zinc is prepared from ores (oxides, sulphides or carbonates) by roasting and subsequent distillation with carbon.

*Properties*—It is a bluish white and easily fused metal. It is brittle when cold, but malleable at a high temperature and can be rolled into sheets. It is easily effected by acid fumes. Weight$=7{\cdot}29$ gm/cm$^3$; Melting Point=420°C.

*Use*—It is used for galvanising steel sheets, roofing, pipes, cisterns, ventilators, slating nails, alloys, etc. Its oxide is used as a base for zinc paint.

Zinc is also used in brass making, and negative pole pieces for batteries.

### 5.32.4 *Tin*

*Manufacture*—Tin is obtained from its ores tin pyrites or tin stones. The ore is roasted and washed, a flux is added and after smelting in a reverberatory furnace the liquid metal is run off into the moulds and then the ingot is refined.

*Properties*—It is a white metal, very soft and malleable but its ductility and tensile strength are very low. It fuses at a lower temperature than other metals and oxidises very slowly. Weight$=7{\cdot}3$ gm/cm$^3$; Melting Point=232°C.

*Use*—It is used for tin plating, lining lead pipes, alloys and solders.

Steel sheets coated with tin are used for making cans for food, milk and fruit industry. In its pure form it is used for manufacture of foils for wrapping cheese and for collapsible tubes.

### 5.32.5 *Aluminium*

*Manufacture*—The extraction of Aluminium consists of two operations :

(1) Purification of its ore bauxite ($Al_2O_3$, $2H_2O$) and

(2) Electrolysis of purified bauxite to get Aluminium.

*Properties*—It is a tin-white metal. It is malleable, ductile, and very light but it possesses great toughness and tensile strength. It is a good conductor of heat and electricity. It is a highly electropositive element and is capable of reducing a number of other metals from their combinations with oxygen or sulphur. Aluminium is scarcely acted upon by nitric acid, organic acids, or water but readily dissolves in hydrochloric acid. Weight = 2·7 gm/cm$^3$ ; Melting Point = 658°C.

*Use*—It is used as a reducing agent ; in the manufacture of steel ; in electric industry ; for making alloys (*Aluminium bronze* looks like gold) ; in the manufacture of cooking utensils, surgical instruments, etc. ; in making parts of air-ships ; in the casting of steel ; and Al-powder is used as a paint, in pyrotechny and in flash-light photography.

Alloyed aluminium is used for making cylinders and pistons in aeroplane engines. It is also used for making automobile bodies, utensils and cables.

5.32.6 *Nobel Metals.* Gold, silver and platinum come under the category of nobel metals.

5.32.6.1 *Gold.* It is found in veins among rocks and along with ores of other metals. It is also found as gold dust in the river beds.

It weighs 19·3 gm/cm$^3$ and has a Melting Point of 1063°C. It can be beaten to sheets of ·0000/mm thickness.

It is extensively used for making coins and jewellery.

5.32.6.2 *Silver.* It is mostly found in ores containing silver compounds. In malleability and ductility it is next only to gold. It weighs 10·5 gm/cm$^3$ and is best conductor of heat and electricity.

On account of its sensitivity to light, silver is extensively used for the production of photographic film and paper. It is also used for coinage, jewellery and household wares.

5.32.6.3 *Platinum.* Grayish white metal, very hard and highly corrosion resistant. It weighs 21.45 gm/cm$^3$ and melts at 1773°C. It is not affected by air, water, hydrochloric and sulphuric acids.

It is generally alloyed with gold, iridium and iron to produce more useful metals.

As an alloy it is used for jewellery, electrical contents and surgical instruments.

### 5.33 Other useful metals

The following uncommon metals are used as components of some alloys used in engineering trades and industries :

*Beryllium* (Be) is a light steel-like metal, does not corrode and transmits long-wave X-rays. Weighs 1·84 gm/cm$^3$, Melts at 1350°C.

*Chromium* (Cr) is a white metal and is used as a corrosion resisting plating. Weighs 6·9 gm/cm³ and melts at 1510°C.

*Cobalt* (Co) is a white metal and is used in cutting alloys and tool steel, magnet steel and electrical alloys. Weighs 8·76 gm/cm³ and melts at 1495°C.

*Iridium* (Ir) is a hard corrosion-resisting alloy when alloyed with platinum and used for pin-points, watch and compass bearings, crucibles and standard lengths. Weighs 22·42 gm/cm³ and melts at 2454°C.

*Manganese* (Mn) is used in many varieties of brass, bronze and other alloys. In the manufacture of steel it is used as a reducing agent.

*Molybdenum* (Mo) is used in some alloy steel and in making *permalloy* and *stellites*. Weighs 10·2 gm/cm³ and melts at 2625°C.

*Nickel* (Ni) is used as an alloy metal in some types of steel and other metals. Weighs 8 gm/cm³ and melts at 1452°C.

*Osmium* (Os) is the heaviest metal and used with iridium for making pin-points, compass bearings, etc. Weighs 22·48 gm/cm³.

5.33.1 *Tantalum.* Highly ductile grayish white metal. It weighs 1664 gm/cm³ and melts at 2850°C. Used as an alloy in the manufacture of high speed steel.

5.33.2 *Tungsten* (W) is used as a filament of electric lamps and as a constituent of high-speed tool steel and magnet.

Generally obtained in the form of hard and brittle powder. It weighs 18·8 gm/cm³ and melts at 3400°C. It gives the special property to the steel which enables it to maintain the edge cutting property at red heat temperature. It is thought extensively used as alloying material for high speed and cutting steel.

5.33.3 *Zirconium.* When alloyed with steel, it gives the same qualities as that given by titanium i.e. improves the quality of steel in respect of abrasive and frictional wear. It weighs 6.49 gm/cm³ and melts at 1850°C.

5.33.4 *Vanadium* (V) is used as a constituent of alloy steel. Its weight is 6·1 gm/cm³ and Melting Point is 1750°C. It is extensively used as an alloying agent in the manufacture of wear-resisting steel. For speed cutting tools and spring steels vanadium is alloyed with chromium.

5.33.5 *Titanium.* Very widely found mixed with iron ore. It is added in small quantities in the manufacture of steel. It weighs

4·5 gm/cm$^3$ and melt at 1900°C. Used extensively for alloying steel for sheet metal work and jet engine compressor parts. The abrasive and friction resistant qualities of steel are improved by alloying the metal with it.

## 5.34 Alloys

It is an intimate mixture of two or more metals together. Alloys are prepared by melting the more infusible metal first in a fireclay crucible, the other or others being added later in the order of their infusibility, continually stirred for homogeneous mass and then the molten metal is cast into moulds. The tensile strength of an alloy is generally greater than that of its constituents. It is not the result of a mechanical mixture as its properties are so different from its constituents. Alloy produced by mixing copper and zinc is called copper-zinc alloy or *brass* and that of copper and tin is called copper-tin alloy or *bronze*.

**Composition and use of principal alloys**

| No. | Alloys and their use | Parts by weight of constituents | | | | |
|---|---|---|---|---|---|---|
| | | Copper Cu | Zinc Zn | Tin Sn | Lead Pb | Al |
| 1. | *Brass*, survey instrument | ·69 | ·3 | ·01 | | |
| 2. | ,, taps | 2 | 1 | | | |
| 3. | ,, door handles, locks, etc. | 3 | 1 | | | |
| 4. | ,, turning and fitting | 3 | 1 | | $\frac{1}{12}$ | |
| 5. | ,, name plate | 3 | 1 | little | | |
| 6. | ,, naval work | 62 | 4 | 1 | | |
| 7. | *Bronze*, stop cocks and valves | 88 | 33 | 2 | | |
| 8. | ,, bell metal for small bells | 5 | | 1 | | |
| | ,, ,, ,, ,, big ,, | 4 | | 1 | | |
| | ,, ,, ,, church ,, | 3·5 | | 1 | | |
| 9. | ,, gun metal | 9 | | 1 | | |
| 10. | ,, machinery hard bearing | 8 | 10 | 1 | | |
| 11. | ,, Aluminium | 9 | | | | 1 |
| 12. | *Muntz metal* for nails | 87 | 4 | 9 | | |
| 13. | *British copper coins* | 95 | 1 | 4 | | |
| 14. | *Pewter, utensils* | | | 6 | 1 | |

The important alloys of aluminium are as follows :

**5.34.1** *Duralumin.* Al 94, Cu 4, Mg, Mn, Si, & FeO 0·5 each. Used in making cables. It takes high polish and is an ideal substitute for Aluminium.

*Y-alloy.* Al 92, Cu 4, Ni 2, Mg 2. Used for making pistons for engines. It possesses high strength even at elevated temperature.

**5.34.2** *Aluminium Bronze.* Al 10, Cu 90. Used for die casting and pump rods. Solar solution of copper and aluminium. Has high tensile proportion and wear resistance.

Alloys of aluminium are light and so these are called *light alloys.* Other important alloys :

**5.34.3** *Coinage Bronze.* Cu 95, Sn 5. Used for making bronze coin.

**5.34.4** *Cartridge Brass.* Cu 70, Zn 30. Used for cartridges.

**5.34.5** *Admiralty Metal.* Cu 88, Pb 27, Sn 10. Used to resist marine corrosion and for engineering castings.

**5.34.6** *Phosphor Bronze.* Cu 89, Sn 10, P 1. Used for bearings and gears.

**5.34.7** *Delta Metal.* Cu 60, Zn 37, Fe 3. Used for mild steel. It resists corrosion.

**5.34.8** *German Silver, Nickel Silver, Electrum.* Cu 60. Zn 35, Ni 5. Used for utensils and fittings. Hard, tough and can be hammered and decorative articles.

**5.34.9** *Antifriction Bearing Metals.* These alloys (white metal) are made up ot Tin, Antimony, Copper and Lead. These alloys are used to line steel, cast iron or bronze heavy duty bearings. The first three metals forms some hard compounds which take up the wear of the bearing but lead provides a soft bearing surface.

**5.34.10** *Babbit Metal.* Is a special white metal containing 80 to 90% tin, 5 to 10% copper and 8 to 10% antimony. In bearing hard particles resist wear and soft particles equalise the bearing pressure.

**5.34.11** *Momel Metal.* 67% Ni ; 28% Cu ; 3% Fe ; 2% Mn. It is strong, tough and ductile as steel. Resistant to corrosion, steam attack and high temperature. Used for stream valves, turbine blades, pump etc.

**5.34.12** *Inconel.* 80% Ni, 14% Cr, 6% Fe. It has extremely good resistance against corrosion and wear. Used in springs, engine exhaust manifolds, heat treating equipment which are subjected to high temperature and corrosive conditions.

**5.34.13** *Illium.* 60% Ni, 6% Cu, 6% Fe, 22% Cr 6% Mo. It is machinable and can be easily welded : Used for corrosion resisting applications.

**5.34.14** *Hastelloys.* The alloys are divided into four different groups in which the components vary as per details given below :

| | |
|---|---|
| Ni | 60% to 87% |
| Fe | 5% to 20% |
| Mo | 10% to 30% |
| Cr | 15% in the third category of |

The fourth category has 87% Ni, 3% Cu and 10% Si. The alloys are particularly useful in situations when the surface comes in contact with mineral acids.

**5.34.15** *Zinc Alloys.* 3·5 to 4·5% Al, ·1 to 2·5% Cu, along with very small quantities of Su, Cd, Mg, Pb. These alloys are used for the manufacture of automobile bodies, hardware and refrigerator parts.

**5.34.16** *Cobalt Alloys.* The chief elements which alloy with cobalt are chromium, nickel, molybdenum and tungsten. Cobalt alloys behave better at elevated temperature that nickel chromium alloys.

**5.34.17** *Solder.* It is an alloy used for joining two or more pieces of metal together by partial fusion. A *hard solder* is one which melts at a very high temperature. The most common hard solder used for joining copper, brass, iron and steel is an alloy of copper and zinc. A *soft solder* is one which melts at a low temperature. It is an alloy of tin and lead, used for joining lead, tinned iron, zinc and copper.

**5.34.17.1** *Brazing* is the process of making joints in iron, copper, brass and gun metal with hard solder and is generally done by heating in an Open-hearth. The mixture of granular solder, borax and water is the usual flux.

### 5.34.17.2 *Composition and Use of Principal Solders*

| Solders and their use | Parts by weight of constituents | | | | |
|---|---|---|---|---|---|
| | Copper Cu | Zinc Zn | Tin Sn | Lead Pb | Silver Ag |
| *Hard solder* | | | | | |
| Brass solder—soft, for | | | | | |
| common brass articles | 1 | 1 | | | |
| —hard, for copper, | | | | | |
| iron, steel | 3 to 6 | 2 | | | |
| Silver solder—soft | 1 | | | | 2 |
| —hard | | | | | 3 |
| —very hard, for | 1 | | | | |
| silver, copper, brass | 1 | | | | 4 |
| *Soft solder* | | | | | |
| Tinman's solder | | | | | |
| —common | | | 2 | 1 | |
| —very fusible | | | 4 | 1 | |
| Plumber's solder—soft | | | 1 | 1 | |
| —common, for | | | | | |
| lead works | | | 1 | 2 | |
| —coarse | | | 1 | 3 | |

## 5.35 Preservation of metal

Most of the metals corrode when they come in contact with moist air or water. This is due to the oxidation of the surface layers of the metal and hence the need for preservation of the metal by giving treatment to the surface. The commonly followed method for this are as below :

1. *Painting* : The coating of the paint should be impervious to moisture and should not crack.

2. *Metal Coating* : The metal coating may be applied by (i) dipping (ii) electroplating (iii) spraying.

3. *Zinc plating or galvanising* : Zinc coating is applied by dipping the article in molten zinc. This method is largely used for sheets, gutters and wire fences. An improved method of surface coating is galvanising. The metal to be coated is cleaned and then packed in zinc dust at 300°C to 400°C for several hours.

4. *Tin plating* . Iron, copper and other metals are given a thin film of tin by passing the sheets through a bath of zinc chloride and then through baths of molten tin at 330°C.

*Chromium plating :* Before chromium plating the articles are nickel or copper plated to prevent the beating off of the coating. This coating is generally applied to hardware, automobile, machine parts of articles made of brass, bronze, copper, nickel, cast iron or steel.

## 5.36 Indian methods of manufacturing iron

In olden days the manufacture of iron by Indian methods was widely practised throughout India. It has always been held in great estimation on account of its purity and malleability. Indians were noted for their skill in tempering of steel. The wrought iron pillar close to Kutab Minar near Delhi weighs about ten tons, and is about 1,500 years old, the ornamental gates of Somnath, wrought iron girders at Kanarak near Puri and 7 m wrought iron gun at Nurvar bear testimony to the marvellous metallurgical skill of the Indians of the bye-gone days. The competition of English iron has extinguished the Indian outturn in many places since the opening of railway communications. Now-a-days English methods of manufacturing iron are adopted in India in a large scale to withstand the competition of imported iron. The Indian method of manufacturing iron still survives in a few places. .The method of smelting is simple and the apparatus used is very cheap. The quality of iron produced is excellent but the quantity is very small.

The furnace used for iron smelting is built of clay and conical in form, about 1·5 m high and the maximum yield per furnace being about 30 tonnes per year. The fuel used is charcoal and no flux is added with the softer varieties of ore used for the purpose. The blast is supplied by a pair of leather bellows worked alternately and introduced in the furnace by clay tuyers at the base. During the operation slag is removed through slag holes. The ore is reduced to a plasty mass by coming in contact with charcoal. The iron is refined by heating and hammering several times.

## 5.37 Prospects of iron manufacture in India

The main points to be looked into for developing an iron industry are as follows :

(1) The quality and quantity of iron ores available, (2) the flux, (3) the fuel, (4) the distances of the quarries from the site of work, and (5) labour. India possesses a great natural advantage for manufacture of iron owing to the abundance and richness of the iron ore deposits very close to coal mines and limestone hills. Materials of refractory bricks for furnaces are also in abundance in India. Now-a-days skilled labourers from abroad are replaced by Indians adequately trained and so labour cost is coming down gradually. The Indian market for iron and steel is already large and will grow still.

**5.38 Principal iron and steel works in India** are as follows :

I. *Private Sector.*

*1. The Tata Iron & Steel Co. Ltd. at Jamshedpur (Bihar). Production capacity 1·75 million tons.

2. The Mysore Iron & Steel Works at Bhadravati (Mysore). Production capacity—Pig iron 101600 tonnes, Steel 60960 tonnes, Rolled Steel Sections 50800 tonnes, C. I. Pipes 30480 tonnes, C. I. plate sleepers 12212 tonnes and other castings 7112 tonnes.

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* In the year 1908 the limited company of an extensive iron industry has been started at Sakchi (now called Jamshedpur in the district of Singbhum) by the renowned Parsee merchant Mr. Jamshedji Tata and his son Sir Dorab Tata. Pig iron was first produced in 1911 and steel in 1913. In 1919 His Excellency Lord Chelmsford visited the iron works and changed the name of Sakchi to Jamshedpur in honour of the founder of the works.

The ore used is red haematite obtained from Gorumohisanee hill about 4 miles from the site of works. Flux used is limestone from Panposh and dolomite from Balaghat both about 160 km away from the works and fuel is coke from coal obtained from Jharia about 112 km away from the place.

The existing plant consists of the following units : 1. Coke-ovens, 2. Benzol recovery plant, 3. Five Blast furnaces, 4. Open-hearth plant—Eight stationary Basic Open-hearth furnaces and two electric furnaces, 5. Duplex plant—Three tilting Basic Open-hearth furnaces with three acid Bessemer Converters, 6. Rolling mills, 7. Boiler plant, 8. Electric power plant, 9. Mechanical and maintenance shops, 10. Magnesite brick plant, 11. Control and research, and 12. General.

3. The Indian Iron & Steel Co. Ltd. at Burnpur & Kulti, (Bengal).

   Production capacity—Pig iron 1016000 tonnes, Castings 152400 tonnes.

II. *Public Sector* (under Indian Govt.):

1. At Rourkela (Orissa) with the help of West German firms. Annual steel production 1 million tons.
2. At Durgapur (West Bengal) with the help of British firms. Annual steel production 1 million tons.
3. At Bhillai (M. P.) with the help of U. S. S. R. Govt. Annual Production—Rolled Steel Sections 772160 tonnes and foundry products 30480 tonnes.

## Exercise V

### A. M. I. E. (1) Examination Questions

1. (a) Explain the term pig iron. How is it manufactured on a commercial scale? What are its chief uses in engineering industry? (b) Starting from pig iron, how would you manufacture steel of different grades? (c) What is the type of steel you would use in (i) reinforced cement concrete, (ii) pre-stressed cement concrete, (iii) cables of suspension bridge? (Nov. 1961)

2. (a) Distinguish between the acid and basic process of manufacture of steel. (b) Describe in detail, the manufacture of steel by the basic Open-hearth process. (May 1961)

3. Describe the manufacture of mild steel and its properties and uses. (Nov. 1960)

4. Write short notes on: (a) solders and brazing alloys, (b) grey and white cast irons, (c) protective coatings employed for prevention of corrosion of iron and steel, (d) aluminium or copper and its alloys used in industries. (May 1960; Nov. 1956)

5. Explain the principles involved in extracting iron from its ores. Briefly describe the physical and mechanical properties of cast iron, wrought iron and steel. (May 1960)

6. Mention the location of principal iron and steel works in India. How would you manufacture charcoal iron in a blast furnace? (May 1959)

7. Describe the Open-hearth process of manufacturing steel, giving a diagram of the furnace used. What are the hardening, tempering and annealing with reference to steel? Tabulate the chief physical and mechanical properties of cast iron, wrought iron and steel. (May 1958)

8. Draw a neat sketch of blast furnace and describe its working. (May 1958)

9. Explain the terms (a) pig iron, (b) cast iron, (c) wrought iron, (d) mild steel. Describe the chief characteristics of each. (May 1957)

10. Describe one method of manufacturing plain carbon steel. (May 1957)

11. Write short notes on : (a) solders and brazing alloy, (b) grey and white cast irons, (c) protective coatings employed for protection of corrosion of iron and steel, aluminium or copper and its alloys used in industries. (Nov. 1956)

12. Describe briefly with sketches the different processes through which a suitable grade of pig iron has to be passed before its conversion into wrought iron. (May 1956)

13. What are (a) yellow brass, (b) gun metal, (c) phosphor bronze, and (d) nickel silver? Indicate the influence of tin, lead and manganese on the properties of brass. (Nov. 1955)

14. What is mild steel and how does it differ from cast iron, wrought iron and high carbon steel? Give an account of the acid Bessemer process of making steel, and indicate the specific uses of the metal. How does it differ from the basic open hearth steel? (Nov. 1955)

15. Describe the process of the manufacture of grey cast iron. Give the composition, properties and applications of grey cast iron. (Nov. 1955)

16. Give a brief outline of the blast furnace process of the manufacture of pig iron indicating the factors that control composition and quality of the metal. (May 1955)

17. Give a brief outline of the basic open hearth process of making low carbon steel. How does the metal differ from wrought iron and cast iron? What is meant by heat treatment of steel? How does it modify the properties of the metal? (May 1955)

18. Give the composition and uses of phosphor bronze and naval brass. (Nov. 1954)

19. What are the characteristics of cast iron, wrought iron, and mild steel? Describe briefly Bassemer's process of manufacture of steel. (Nov. 1952)

20. (a) What are the important iron ores? Give their composition and the percentage of pure iron obtained from each.

(b) Describe with sketches the process of manufacturing pig iron from the ore.

(c) Specify some important purposes for which cast iron is put to in engineering works. (May 1952)

21. (a) What are the serious defects in steel ingots and other steel castings, and what methods would you suggest for reducing these defects?

(b) Sketch the essential parts of a blast furnace, and describe its functions. (May 1952)

22. (a) What are the chemical differences between cast iron, wrought iron and steel? State their uses as engineering materials.

(b) Describe briefly the Bessemer's process for the manufacture of steel.

(c) Explain with sketches: (i) Galvanised corrugated iron 22 B. W. G., (ii) Rolled beam 10″ × 4½″, (iii) Angle iron 3″ × 3″ × 5/8 in. (Nov. 1950)

23. Write short notes on : fine solder, soft solder, brass, bronze, pewter (Apr. 1950)

24. What are the impurities of iron ore ? Show with the help of a neat sketch how pig iron is manufactured in a blast furnace and how the impurities are eliminated. (May 1964)

25. (a) Explain acid and basic processes steels.

(b) What is the effect of carbon sulphur and phosphorus on the properties of steel ? (May 1965)

26. Describe the properties of aluminium as a bending material. (May 1965)

27. Write short notes on any three types of non-fusion metal and describe the uses of alloys made with those. (May 1966)

## Engineering Services (I) Examination Questions

28. (a) Give a brief outline, with neat sketches, of the open-hearth process of manufacturing mild steel on a commercial scale, stating the fuel used, the temperature maintained and the generative principle of the furnace. (b) How does it differ from the Bessemer process of making steel ? (c) Sketch the various forms of mild steel obtained in the market. (1962)

29. From what ores is iron chiefly obtained in India ? Explain the process of manufacturing pig iron from its ores and the different chemical reaction that takes place in the furnace. What is the characteristic difference between cast iron. and mild steel ? Name and sketch the market sections of steel. (1960)

30. Describe the manufacture of steel from cast iron to ingot by the basic Open-hearth process paying particular attention to the chemistry of the process (a very brief description of the furnace will suffice). Compare the product with that of the acid open-hearth and of basic Bassemer process. (1959)

## Other Examination Questions

31. From what ores is iron chiefly obtained in India ? Describe with sketches the process of manufacturing pig iron from the ore.

32. Name the principal iron ores, giving their composition and the precentage of pure iron obtainable from each.

33. Describe briefly with sketches the different processes through which an iron ore is to be passed before wrought iron is obtained. What is chilled casting, wrought iron and steel ?

34. Explain the terms : Blister steel, tempering, case hardening, alloy, soft solder, bloom, red short iron, and cold short iron.

35. Describe briefly with sketches Bessemer process of converting cast iron into steel.

36. Describe the manufacture of 'Mild steel' on commercial scale. Sketch the various forms in which it is obtained in the market.

37. What is pig iron and why is it so called ? How are castings made from it ? What points would you attend to in the examination of casting ?

38. Mention the different kinds of steel, and state which is the strongest and most uniform and how it is produced. What kind of steel would you use for the following : (1) bridge work, (2) cutting tools, (3) spring, and (4) joists.

39. Why are the following metals chiefly used for in Engineering works : copper, lead, zinc, tin and aluminium. What alloys are frequently used in Engineering works and to what uses are they put ?

40. What are the characteristics and principal uses of cast iron, wrought iron and steel ? What kind of iron will you use for the following : joists, rail, bars, facing hammer, farmer's chisel, large knives, shears and drills.

41. What are the main physical differences between cast iron and mild steel ? Illustrate your answer by drawing a stress strain diagram showing the behaviour of each metal under tension up to breaking point.

42. What takes place in the process of the rusting of iron ? How can you prevent it?

43. What is galvanised iron and how is it made ? Give some examples of the uses to which it is put.

44. Distinguish between Bessemer steel and Sieman Martin process of making steel.

45. Explain with sketches, what you understand by (1) galvanised corrugated iron 20 B. W. G. (2) ∠ iron 3″ × 3″ × $\frac{1}{4}$″ (3) rolled beam 16″ × 6″ × $\frac{[illegible]}{16}$″ (4) 1″ hoop 18 B. W. G. (5) wire netting 2″ mesh, (6) expanded metal 4″ × 2″ mesh.

46. How are castings obtained ? Describe briefly the process of casting any article of simple shape.

47. What is meant by cold-short iron and red short iron ? What are the causes of these defects ?

48. What is a rivet ? What is meant by pitch ? What is the minimum pitch ? What are the usual sizes of rivets for $\frac{1}{2}$″ and $\frac{1}{4}$″ plates ?

49. What is an alloy ? Give composition of the following alloys : brass for hinges, gun metal, bell metal and bronze for statues.

50. What is cast iron and how is it obtained and for what purposes is it used in Engineering works ?

51. What is bolt ? What is minus thread and plus thread ?

52. What is pig iron ? What are the varieties used for different purposes ? Describe the characteristics of each variety.

53. Describe with sketches, the process of manufacturing cast iron from the ore. How do white cast iron, grey cast iron, steel and wrought iron differ from each other in composition and physical properties ?

54. What is corrugated iron ?

# Chapter 6

## PAINTS AND VARNISHES

### 6.1 Paint

Is usually a coloured liquid applied on the surfaces of engineering materials by means of a brush.

### 6.2 Use

Paints are used by builders and engineers for covering the surfaces of building and engineering materials, such as, timber, iron etc., (1) to protect them from the effects of the atmosphere, (2) for decorative purposes, (3) to prevent the leaking out of preservative, and (4) to provide a surface which may be cleaned easily.

### 6.3 Classification of paints

Paint is roughly divided into 4 classes :

(a) *Oil paint*, (b) *Enamel paint*, (c) *Washable water-paint*, and (d) *Distemper*.

### 6.4 Constituents of paints and their functions

Paints are composed of the following components in general :

(1) *base*, (2) *inert filler* or *adulterant*. (3) *vehicle* or *carrier*, (4) *drier*, (5) *solvent*, and (6) *pigment* or *stainer*.

Paints used by engineers consist of a *base* generally a metallic oxide which gives opacity and covering power to the paint. The bases of paints are diluted or extended with inert materials called *fillers* for correcting the weight of paint, making it lighter or heavier and to lessen its cost. These are also called *adulterants*. A *vehicle* or *carrier* is a liquid of drying nature capable of dissolving and holding in suspension bases and pigments, and to enable them (bases and pigments) to be spread in a thin and even coat. In most cases a *drier* is added to help the vehicle to dry up quickly. A *solvent* or *thinner* is also sometimes used in paint to make it work more freely. The required tint of paint is obtained by adding a *stainer* or *colouring pigment* when the desired final colour differs from that of the base used.

### 6.5 Materials commonly used in paints

*Bases.* White lead 2Pb $CO_3$. Pb $(OH)_2$, red lead $Pb_3O_4$, zinc white ZnO, oxide of iron $Fe_3O_4$. *Titanium white* $TiO_2$ (Titanox) possesses intense opacity, even better than white lead and is very invaluable as an under coat to enamel.

*Inert fillers.* Barytes, silica, whiting, gypsum, charcoal, silicates of alumina and magnesia.

*Vehicles.* Linseed oil (raw or boiled), nut oil, poppy oil, spirit of turpentine.

*Driers.* Litharge, red lead, sulphate of manganese and zinc, acetate of lead, verdigris.

*Solvents.* Spirit of turpentine, oil of turpentine or turps.

*Colouring pigments*—

*Black* : Lamp black, ivory black, vegetable black.
*Blue* : Indigo, Prussian blue, cobalt blue.
*Brown* : Raw umber, burnt umber, Vandyke brown.
*Green* : Crome green, verdigris.
*Red* : Carmine, Indian red, red lead, vermilion.
*Yellow* : Crome yellow, raw sienna, yellow ochre.

**6.5.1** *Bases.* Paints are classified into 1. *Lead paints*, 2. *Zinc paints*, and 3. *Oxide of iron paints* according to the base used in paint.

1. *Lead paint.* The base is either red lead or white lead. Red lead paint is used for painting iron work and for the priming coat of wood work. White lead paint is a cheap paint but it has the disadvantage of turning black when exposed to sulphur vapour in laboratories and manufacturing towns and is also injurious to painters.

2. *Zinc paints* or *zinc white paints.* Oxide of zinc forms the base. It is more costly and has less covering power than white lead

paint but not affected by sulphur vapour nor harmful to painters. It is mostly used in large manufacturing towns subjected to sulphur vapour.

3. *Oxide of iron paints*. Oxide of iron forms the base. Colour varies from yellowish brown to black. It is chiefly used for painting iron works.

6.5.2 *Vehicles*. Oils used as vehicles are of two classes : 1. *fixed oils* extracted by pressure from vegetable substances e.g. linseed, poppy and nut oils ; 2. *volatile oils* obtained by distillation e.g. turpentine.

*Raw linseed oil*. It is pale in colour, transparent, sweet in taste and free from smell. It works smoothly but dries slowly. It is suitable for delicate tints and interior painting.

*Boiled linseed oil*. It is prepared by boiling the oil itself of when mixed with certain driers to a temperature varying from 130°C to 275°C. It is thicker and darker in colour than raw oil and dries quickly. It is not suitable for delicate tints but used for outdoor works.

Linseed oil is superior in drying power, tenacity and body to other fixed oils used as vehicles.

*Poppy oil* is extracted from poppy seeds. It is used for delicate colours but inferior in drying.

*Nut oil* is extracted from walnut. It is practically colourless and less durable but dries rapidly.

*Turpentine* is colourless but on exposure to air and light becomes darker and thicker.

6.5.3 *Driers*. Driers should not be added to a paint until it is about to be used and never more than one kind of drier is to be used in a paint. It should not be used with pigments that dry well in oil. It retards drying and injures the paint if used in excess.

6.5.4 *Solvents*. Turpentine is produced by distilling the resinous exudation of some pine trees. It is affected by weather and so it is used only for interior painting and making varnishes. It should be added in small quantity if used at all in exterior work.

6.5.5 *Colouring Pigments*. These are used only when final colour differs from the base used.

## 6.6 Covering power of paint

The covering power of a paint is an important factor in its final cost. The *covering power* or *capacity of a paint* is the amount of surface

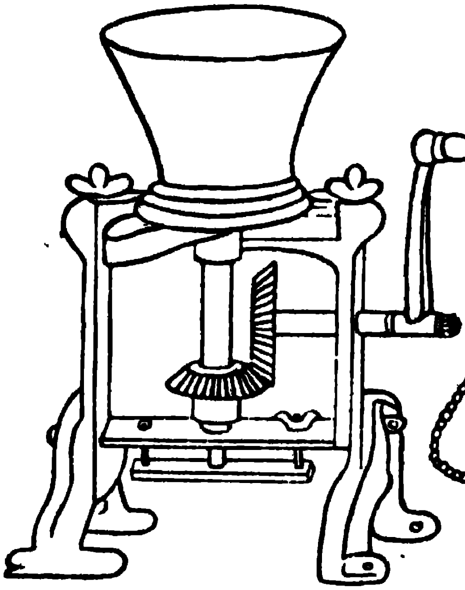


Fig. 6.1 Paint mill

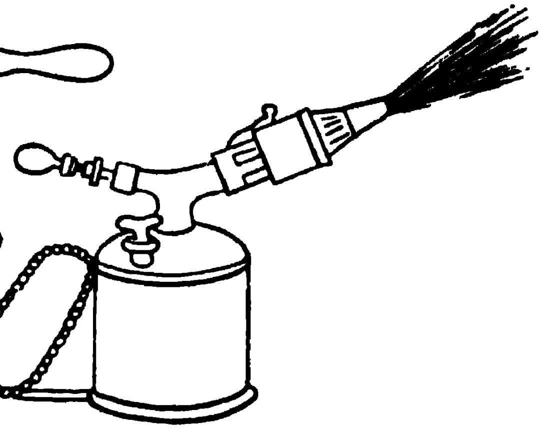


Fig. 6.4 Blow lamp

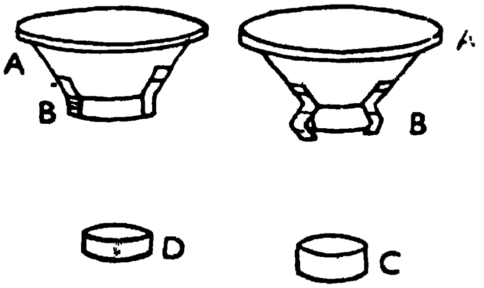


Fig. 6.2 Strainer

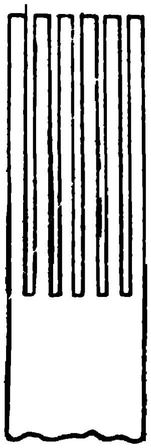
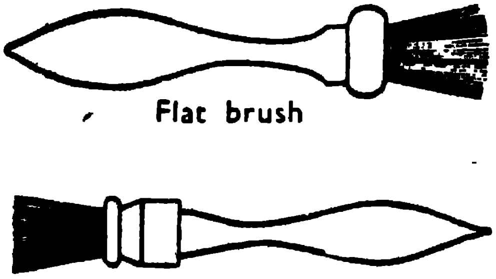


Fig. 6.5 Graining comb



Flat brush

Bevelled brush

Fig. 6.3 Brushes

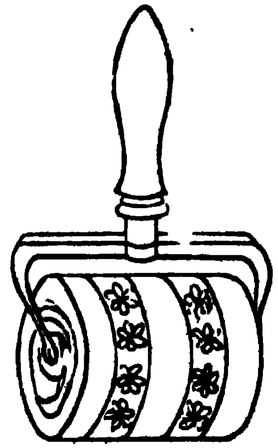


Fig. 6.6 Graining roller

a given quantity will cover when mixed to a consistency suitable for application by brush. Other things being equal, the degree of absorbency of a surface will determine the *spreading power of a paint.* Metals are no-absorbent, wood varies according to kind and condition but cement and plaster are most absorbent.

### 6.7 Characteristics of a good paint

The paint should (1) be liquid enough to be applied with a brush or spray, (2) dry within 48 hours, (3) adhere firmly to the surface to which it is applied, and (4) be impervious, smooth and resist wear and tear to some extent when dried up, (5) High covering capacity. It is measured in square metre per litre, (6) It should produce gloss and washable film, (7) The paint should not leave any brush marks on drying, (8) During and after drying it should not leave shrinkage marks, (9) The film provided as a result of painting should be tough and durable, (10) If colouring matter is added to give a particular shade, the same should not fade with time, (11) The appearance should be durable pleasing and attractive, (12) If should not have any injurious effect on the surface to which it is applied and not to the workman.

A good paint should have also a good covering power, not crack in drying and not fade in colour under atmospheric action.

### 6.8 Preparation of paints

The base and the pigment are first ground with a small quantity of oil in a muller (a stone pestle for grinding colours). The pasty mass thus formed is thinned with oil to the proper consistency. Finally turpentine and suitable drier in required quantities are added and mixed up. A *paint mill* (Fig. 6.1) is desirable for grinding up rough colour and is constructed on the cone principle with a side handle. *Strainers* (Fig. 6.2) for paint and distemper are necessary. Those which allow of the gauge being readily replaced by new ones are the most convenient. The clip *B* secures the band *C*, and thus firmly holds the gauge *D* in position.

### 6.9 Various paints

*Enamel paint* consists of metallic oxide (white lead or zinc white) ground with a small quantity of oil and mixed with petroleum spirit holding resinous matter in solution. It forms a hard and enamel like substance which is proof against water, hot or cold, and steam or acid fumes. It is found ready-made in all shades of colour.

*Enamel* consists of a paint in which drying oil is partly replaced by varnish. It has the property of flow which leaves no brush marks but paint has no such property.

*Aluminium paint* consists of fine ground aluminium suspended in quick-drying spirit varnish or slow-drying oil varnish. It protects iron from corrosion better than any other paint and so it is largely used for painting gas tanks, oil storage tanks, marine pipes, etc. It is also applied to radiators, hot water pipes, etc. as it resists heat to a certain extent.

*Cellulose paints* are different from linseed oil paints and varnishes. Cellulose is made from nitro-cotton. These can be more easily washed and cleaned and possess greater hardness, smoothness and flexibility. These stand extreme heat and cold and so these are far superior to ordinary paints though a bit costly.

*Ready-made paints* of various qualities and colours are available in tins and drums. Generally these are to be thinned with oil or turpentine before use.

*Anti-corrosion paint* consists chiefly of oil, strong drier and a pigment mixed with very fine sand. It is chiefly used for external work, lasting longer and costing less than white lead.

*Asbestos paint* possesses the property of retarding the action of fire and for that reason has been largely adopted for public building.

*Cement paint* consists of boiled linseed oil into which dry portland cement has been stirred until it is as thick as can suitably be spread with a brush. This was tried over ungalvanised corrugated iron sheets during the Great War.

*Coal tarring* consists of one coat of well boiled coal tar laid while hot over surface well cleaned from mud or dirt.

*Paint for black boards or hard courts* consists of a mixture of 583 gms of lamp black and 72 gms of turpentine to cover 9 m$^2$ of surface. It produces a dull surface and does not rub off on clothes and dusters.

*Distempers* : These are cheap paints which can be easily applied over plastered or white washed surface. They are not capable of withstanding the action of weathering and hence normally applied to interior surfaces. Distemper may be (i) Glue bond ore, (ii) Oil bond. The glue bond distemper is prepared from size, a type of powdered glue dissolved in water to which whiting is added as pigment, which is thinned by water. This type of distemper is unsuitable for damp conditions. In the case of oil bond distemper "petrifying liquid" is used as a medium, to which suitable pigment is used. Water is used as thinner.

*Stucco, brick and masonry paints.* As these surfaces are alkaline in nature, the fresh surface is washed with zinc sulphate to reduce alkalinity.

*Tar and bitumen paints.* Tar and bitumen paints consist of these products dissolved in naphtha or white spirit. It provides a very effective surfacing coverage in cases where the black colour is not the governing consideration. Structural steel works are also sometime given a protective cost of tar.

## 6.10 Proportion and nature of ingredients in mix-paints

These should be governed by the following : (1) The kind of surface to be painted, (2) Nature of material to be painted, (3) Nature and appearance of the work to be done, (4) Climate and exposure to which work is subjected, (5) Skill of the painter, (6) Quality of materials, and (7) The different coats.

**Composition and quantities in lbs. of the different coats of white paint to cover 100 sq. yds. of new surfaces**

| | Red lead | White lead | Raw linseed Oil | Boiled linseed Oil | Tur-pen-tine | Driers | Remarks |
|---|---|---|---|---|---|---|---|
| *Inside work*: | | | | | | | |
| Priming | ½ | 16 | 6 | | | ¼ | Besides these materials for every 10 sq. m. 1 kg. white lead and 2 kg. putty are necessary for stopping. |
| 2nd Coat | | 15 | 3½ | | 1½ | ¼ | |
| 3rd Coat | | 13 | 2½ | | 1⅓ | ¼ | |
| 4th Coat | | 13 | 2½ | | 1⅓ | ¼ | |
| *Outside work*: | | | | | | | |
| Priming | 2 | 18½ | 2 | 2 | | ⅛ | |
| 2nd Coat | | 15 | 2 | 2 | ⅓ | 1/16 | |
| 3rd Coat | | 15 | 2 | 2 | ⅓ | 1/16 | |
| 4th Coat | | 15 | 3 | 2½ | | 1/16 | |

### 6.11 Priming

After knotting the priming or first coat is applied without colouring matter before the work leaves the shop or before fitting into work so as to prevent the absorption of moisture. It may consist of one part of white lead to eight parts of chalk ground and mixed together with four parts of twice boiled linseed oil.

Paint with a base of red lead alone or with baryta or with a base of iron oxide should be adopted for priming of iron and steel work. Linseed oil without pigment is not suitable for priming coat as it tends to cause peeling and blistering of paints afterwards. Outer coats should be durable and elastic. The finishing coat should consist of white lead or zinc-white or mixture of both with a little varnish, linseed oil and drier. This also is not suitable for priming on iron or steel as it encourages galvanic action which destroys the paint.

### 6.12 Stopping

Holes, cracks and unevenness of surface are to be filled up with putty or hard stopping after the priming coat and the whole surface must be rubbed with sand paper or pumice stone and well dusted when stopping has hardened.

### 6.13 Second and succeeding coats

These are applied on surfaces, each coat being allowed to dry, rubbed and well dusted before applying the next one.

### 6.14 Flatting coat

The final coat for the interior work consists of paint mixed with turpentine and no oil, causing it to dry with a flat surface. A small quantity of copal varnish is to be added to paint if the surface to be painted is to stand washing.

### 6.15 Applying paints to surfaces

The surfaces to be painted must be perfectly dry because the presence of moisture between paint and material or between two coats is apt to raise blisters. Successive coats should be of moderate thickness for quick drying.

### 6.16 Painting new wood work

New wood work requires 3 to 4 coats of paints. Wood work should be thoroughly seasoned before paint is applied, otherwise timber will be affected by dry rot. The surface should be made clean and smooth, knots killed and holes filled up with hard stopping. Knotting is done in any of the following ways : (1) Ordinary or size knotting, (2) Patent knotting, and (3) Lime knotting. After knotting paints should be applied in the following stages : (1) Priming or first coat, (2) Stopping, (3) Second and succeeding coats, and (4) Flatting coat.

Paint should be applied in coats with proper *brushes* (Fig. 6.3) and spread as smoothly and evenly as possible. Then the brush should be passed over in a direction contrary to that in which it is finally to be laid which is known as crossing. After crossing it should be laid in a direction contrary to crossing. The finished surface should be perfectly smooth without any brush marks.

The settlement of paint in cans is prevented by stirring the paint occasionally. If it is kept aside for a time then it should be covered with water to prevent oxidation and drying. The putty of glazed doors and windows must also be painted and stains from the panes are removed by the application of a little turpentine after the final coat.

*Black paint* consists of one part of chalk, half part of white lead and one quarter of linseed oil mixed with lamp black.

*Green paint* consists of verdigris and white lead in proportion of 11 to 22 by weight, ground separately, screened and mixed together.

*Red paint* consists of two parts of red ochre, three of mineral red lead and four parts of linseed oil, in which pigments are ground and mixed thoroughly

*White paint* consists of mineral white lead and linseed oil in proportion of 5 to 3 by weight, ground and mixed together with a small quantity of Prussian blue and turpentine.

*Satin wood paint* consists of 16 parts of white lead, 1 of crome yellow, 1 of red lead, 2 of red-brown, 2 of amber brown, $\frac{3}{4}$ of terra-sienna, 8 of linseed oil, 4 of turps, and 1 of varnish.

*Mahogany paint* is prepared by mixing colours as for satin wood paint with addition of a little ivory black.

*Chocolate paint* consists of 50 kg oxide of iron mixed with 32 litres of boiled linseed oil and 4·5 litres of turpentine. Stir the mixture for few hours before it is fit for use.

### 6.17 Painting new iron work

First remove all rust and mill scales and then it should be primed with red lead and boiled linseed oil before it leaves the shop. Application of subsequent coats are similar to those of wood work.

### 6.18 Painting new masonry or plastered surfaces

Plastered surfaces will not take oil paint well. A coat of priming consisting of oil paint with little oil and plenty of turps should be applied when the plaster is just hard. It is then distempered and after a year or so it is painted.

*Water paints* : The vehicle in this class of paints is water and these include the following kinds : (1) Whitewash, (2) Colourwash, (3) Whiting, (4) Distemper, and (5) Washable distemper or water paints.

*Water colour* : The wall when dry should be washed with a solution of equal proportion of whiting and best shell lime. A second coat washing of $\frac{1}{3}$ curd and $\frac{2}{3}$ shell lime is applied to the wall after which the colouring mixture is applied which consists of 500 gms whiting powder, 500 cc water, 50 gms glue and colour for the tint as required. Water colour is applied with brush.

### 6.19 Painting over old work

In repairing old work, old paint should be removed carefully either by burning with a *blow lamp* (Fig. 6·9), scraping or with a paint solvent. Generally old wood work is washed with soap and water and then scoured but if foul with smoke or grease, it should be washed with lime and water and rubbed with pumice stone and then it will be washed with soap and water. Old paint may also be removed by wetting it with naphtha and then wiping it with coarse cloth when it is softened. Holes and cracks should be filled with putty. Patches or blister marks are to receive priming coat. The surface is to be repainted in the manner as described.

Iron work with the exception of bolts and rivets is to be scraped quite free from rust, scale and dirt and then brushed with hot boiled linseed oil. It is then painted two coats of oil paint, the first being of red led and the second of colour to be specially approved. The bolts and rivets are to be heated to the temperature of melted lead and then dipped into boiled linseed oil.

If thorough renewal of paint be not necessary, the old work is cleaned with lime wash, rubbed down with pumice stone and holes filled with putty but in case of old iron work signs of rust must be carefully removed by scraping and brushing just before repainting.

### 6.20 Destroying agents

Agents to the decay of paints are changes of temperature, rain, soot and contamination with acids.

### 6.21 Faults in paint

(1) *Blistering* is due to excess of oil in final coat and imperfect seasoning of timber. It is cured by applying water paint finished with oil paint mixed with a little copal varnish. (2) *Crawling paint* is due to too thick coat. It is cured by sand papering the surface and giving a fresh coat with plenty of turps. (3) *Cracked paints*—It is cured by removing paint and giving a fresh coat of paint. (4) *Loss of gloss*—If it occurs in small patches a remedy lies in rubbing the spots with a rag dipped in boiled linseed oil. In severe cases remove paint and give a fresh coat of paint mixed with a little oak varnish.

The cost of protecting a surface is arrived at by considering (a) cost of paint and labour in the initial paint, (b) cost of preparation of surface for repair, and (c) cost of paint and labour for repairing. In general cost of labour involved in paint is ⅘th of the total cost.

### 6.22 Proportion of ingredients for different kinds of paints

| | Materials | |
|---|---|---|
| | Chalk— | ·9 kg |
| For 10 sq. m. of priming 1 coat for white paint | White lead— | ·4 kg |
| | Linseed oil— | ·7 kg |
| | Turpentine— | 30 gm |
| | Red ochre— | ·9 kg |
| For 10 sq. m. of priming 1 coat for red paint | White lead— | ·4 kg |
| | Linseed oil— | ·7 kg |
| | Turpentine— | 30 gm |
| | Red ochre— | ·7 kg |
| For 10 sq. m. of red painting 2 coats | Red lead— | 1·5 kg |
| | Linseed oil— | 1·3 kg |
| | Turpentine— | 60 oz. |
| For 10 sq. m. of white painting 2 coats | White lead— | 2 kg |
| | Linseed oil— | 1·3 kg |
| | Turpentine— | 60 oz. |
| | Verdigris— | ·7 kg |

For 10 sq. m. of green painting 2 coats
White lead— 1·3 kg
Linseed oil— 1·3 kg
Turpentine— 60 gm.

*Spreading capacity of paints and varnishes.* The covering capacity of the paint depends upon the constituents of the paint and the type of the surface on which it is to be applied as well as on the number of the coats. For estimating purposes, however, the following may be taken as guidance.

| | |
|---|---|
| 1 litre lead priming coat | |
| (i) on wood surface | 10 sq. m. |
| (ii) on metal surface | 11 sq. m. |
| 1 litre under coating on flat surface | 11 sq. m. |
| 1 litre gloss paint | 11 sq. m. |
| 1 litre enamel paint | 11 sq. m. |
| 1 litre varnish (first coat) | 12 sq. m. |
| 1 litre varnish (second coat) | 15 sq. m. |

## 6.23 Varnish

It is a solution of resinous substance e.g. common resin, copal, lac, sandarch, etc. in either oil, turpentine or alcohol. It consists of 2 parts of resin, 2 parts of linseed oil and 1 part of turpentine to be well mixed and laid with brush. The liquid dries and leaves a transparent glossy film of resinous substance over the surface varnished.

Use—It is used (1) to protect the surface of engineering materials from the action of the atmosphere or slight friction, (2) to give brilliancy to painted surfaces and papered walls, and (3) to brighten the appearance.

Varnish is used in preference to painting when it is required to brighten the appearance of grains in unpainted ornamental wood works.

6.23.1 *Ingredients.* These are (1) resins, (2) solvents, and (3) driers. The quality of varnish produced is greatly influenced by that of resin used. Common resin, amber, copal, lac, gum anime, mastic, sandarch and gum dammar are some of the principal resins. The gums are exudations from trees. At first these are mixed with some essential oil. When oil evaporates resin is left behind which is solid and bright. Resins are often called gums in practice but a gum is soluble in water and so unfit for varnishes whereas resins dissolve only in spirits of oil. Solvents must be suited to the resinous substances they are to dissolve. Boiling linseed oil is used to dissolve amber, gum anime or copal; turpentine for mastic, dammar or common resin; methylated spirits of wine for lac and sandarch; and wood naphtha is used for cheap varnishes which are less brilliant and having an offensive smell. Driers are used to dry the varnish quickly but a large proportion of driers injures the durability of varnish. Litharge, sugar of lead and white coppers are some of the driers used.

## 6.24 Different kinds of varnishes

These are classified as 1. *Oil varnish*, 2. *Turpentine varnish*, 3. *Spirit varnish*, and 4. *Water varnish* according to the solvent used in them. But sometimes these are called by the name of gum dissolved in them.

1. *Oil varnishes* are made from the hardest gums (amber, gum anime and copal) melted by heat and dissolved in oil. These are the hardest and most durable of all varnishes and so mostly used for exposed work requiring frequent cleaning and polishing.

2. *Turpentine varnishes* are made from soft gums (common resin, mastic, dammar) dissolved in turpentine. These are cheaper and lighter in colour, more flexible and dry quicker but not so durable and tough as oil varnish.

3. *Spirit varnishes* or *lacquers* are made from softer gums (lac) dissolved in spirits of wine. These are more brilliant than turpentine varnishes but do not stand weathering and so are subjected to crack and scale off.

4. *Water varnishes* are made by dissolving lac in hot water mixed with just as much ammonia, borax, potash or soda necessary to dissolve the lac.

It is preferable to use ready mixed varnishes sold in tins and drums as the mixing or preparation of it requires great care and skil.

*Valspar varnish* has many advantages over the ordinary varnishes and it is used for finishing wood work either inside or outside. The best is always cheapest in the long run. There are valspar varnish, valspar varnish stains and valspar enamels.

*Copal varnish* is prepared by dissolving copal in linseed oil and mixing required quantity of turpentine. It is used for best work.

*Japan* is a white or coloured lead paint ground in oil and mixed with copal varnish. It is applied in successive coats. Each coat is dried in turn to the highest temperature it will stand. Then the surface is treated with several coats of copal or anime varnish. It is used in baths and metal works subjected to heat. Common japaned work is not heated but merely painted and varnished.

### 6.25 Polishes

These are thin varnishes which are solutions of ·68 kg of shellac in 4·546 lit of spirit and are lightly rubbed as in the case of brush polish.

*French polish* is a spirit varnish prepared from various gums dissolved in methylated spirit without heat. It may be coloured with some pigments. It is chiefly used for mahogany wood works and is applied by rubbing well into the surface of wood which has been already made smooth with sand paper.

*Lacquer* is a varnish identical with French polish, the different proportion of shellac, methylated spirit and colouring agents will be different for different purposes. Lacquer is made by agitation without heat.

*Recipes for* (1) *furniture polish and* (2) *brass lacquer.*

| 1 | | | | 2 | |
|---|---|---|---|---|---|
| Linseed oil— | 16 kg | Turpentine— | 1 kg | Pale shellac— | 1 kg |
| Methylated spirit— | 2 ,, | Copal varnish— | 1 ,, | Gamboge— | 60 gm |
| Venegar— | 1 ,, | Muriatic acid— | 1½ ,, | Cape aloes— | 200 gm |
| Whole is mixed up with heated oil. | | | | Alcohol— | 9 lit. |

### 6.26 Characteristics of varnishes

The varnish must be tender and soft. It must yield to the expansion or contraction of the wood with heat or cold.

The following points should be taken into consideration in selecting varnish for a work : (1) durability on exposure to weather, (2) hardness of film, (3) toughness of film, (4) elasticity of film, (5) nature of surface—flat or glossy, and (6) colour.

Some varnishes are coloured to act both as varnish and stain.

### 6.27 Application of varnish

The surface to be treated should be made perfectly smooth with sand paper or pumice stone with knotting and stopping. Porous surfaces should be sized to prevent the absorption of varnish.

Everything should be clean, cans kept corked, brushes free from oil and dirt and the work protected from dust or smoke. Then varnish should be applied uniformly in very thin coats sparing at angles and corners. Subsequent coats should not be applied till the preceding one is hard. Varnishes applied to painted surfaces are liable to crack if paint contains too much oil. Varnishes improve when these are kept in a dry place.

*Wood oiling* : Oiling is much more economical than painting. Wood work may be oiled if it is not exposed to weather. *Linseed oiling* consists of a mixture obtained by heating 3 parts by weight of doubled boiled linseed oil and 1 part of bee wax with an addition of 1 part of turpentine when cooled. *Sweet oiling* consists of a mixture of equal parts of common vinegar, country sweet oil and turpentine.

*Stains* : These are liquid preparation of different tints applied to the smooth unpainted surface of cheap light coloured wood to give it the appearance of highly coloured wood of superior quality.

*Waxing* : Melted bee wax and turpentine in the proportion of 2 to 1 by weight is mixed well and allowed to cool. Wood work is smeared with mixture so as to soak into the pores of wood. Superfluous stuff is removed and rubbed with a flannel for polishing.

*Graining* : It is the imitation of the colour and grain of wood upon any painted surface. The graining colour is brushed out in streaks with a thin straight-haired brush and combed with *steel graining comb* (Fig. 6.5).

There are mechanical appliances used for the purpose of imitating the grains of wood. The effect of combing is well obtained by the use of the *patent combing rollers*. These rollers contain a number of notched zinc discs which revolve irregularly and disperse upon the wood work a number of streaks, which are more like the actual open grain of the wood than the marks produced by steel graining combs. The *graining roller* (Fig. 6.6) is also used but it repeats the pattern regularly.

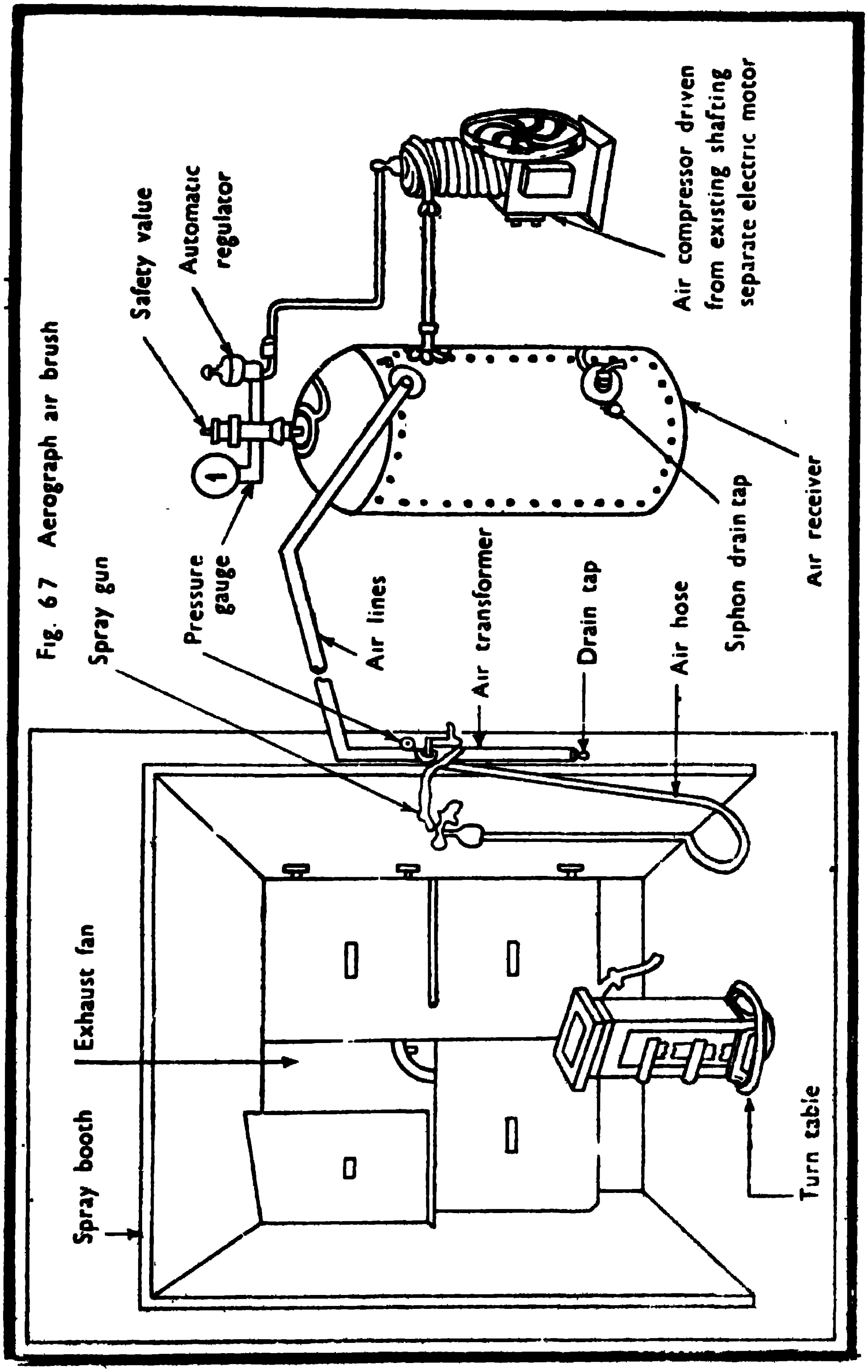


Fig. 6 7 Aerograph air brush

Requirement of varnish for exterior finishing and general purposes : I.S. 525—1968 lays down the following requirements.

| Serial No. | Characteristics | Requirements |
|---|---|---|
| (i) | Drying time max. | |
| | (a) Surface dry | 8 hours |
| | (b) Hard dry | 18 ,, |
| | (c) Tach free | 48 ,, |
| (ii) | Finish | Smooth and glossy |
| (iii) | Colour | Not darker than a combination of 41 yellow units and 10 red units |
| (iv) | Scratch hardness | No such scratch as to show the base metal |
| (v) | Flexibility and adhesion after 96 hours air drying | No visible damage or detachment of the film |
| (vi) | Stripping test, after 96 hours of air drying | Scratches free from Jagged edge |
| (vii) | Flash point | Not below 30°C |
| (viii) | Volatile matter contents % by weight—max. | 60 |
| (ix) | Viscosity at 30°C | 1·5 to 3 |
| (x) | Acid valve—Max. | 25·00 |
| (xi) | Keeping property | Not less than one month from the date of manufacture. |

*Glazing* is used to impart brilliancy to a painted surface by spreading a thin layer of colour.

*Scumbling* is akin to glazing but the colour used is opaque.

### 6.28 Spray painting and spray booth

Spray painting is done by spraying an atomised paint with a spraying 'pistol' worked by compressed air, so as to form a thin and uniform coat of paint on the surface. A spray-painted surface gives shining and perfection which cannot be obtained by hand-painting with brush.

The *aerograph air brush* (Fig. 6.7) is used all over the world now-a-days. Aerograph spray booths and exhaust fans ensure the complete removal of all fumes from the finishing room thus providing comfortable, clean and safe working conditions and resulting in better quality work and increased production.

## Exercise VI

## A. M. I. E. (I) Examination Questions

1. What are the ingredients of paints ? Explain the same with an example of each. (May 1962)

2. What is the object of painting or varnishing a surface and where will you prefer a paint to a varnish and *vice versa* ? (Nov. 1959)

3. Distinguish between oil paint and French polish, explaining the composition of each. (Nov. 1959)

4. What is enamelling ? How is it carried out on simple products ? (May 1958)

5. Distinguish between enamels, lacquers, varnishes, and paints. (May 1957)

6. How would you judge the quality of an oil paint ? Give the requirements of a paint suitable for (a) wood, (b) ferrous metal, (c) cement plaster. Mention the characteristic differences between an oil paint, spirit varnish and pyroxilin lacquar. (Nov. 1955)

7. What is varnish and why is it used ? Classify different kinds of varnish and give brief description of each. What are the qualities to be sought for in good varnish ? (May 1955)

8. Point out the difference between colour wash, distemper and oil paint, indicating the influences of the vehicles, pigments and fillers on their properties. What are the causes of failure in oil paints and how can they be avoided ? (Nov. 1954)

9. (a) What are compositions of oil paints ? Give the utility of each.

(b) What are the chief characteristics of good paints ?

(c) Mention the types of failure commonly met with in paint work and state their causes. (May 1954)

10. (a) Describe the method of removing old paint from wood work and repainting it.

(b) Give the composition of 'French polish' and explain how it is applied. (Nov. 1953)

11. (a) What are the characteristics of a good paint ?

(b) Why are steel structures painted ? Describe the procedure of painting steel structures. (May 1953)

12. (a) What is the difference between a paint, a varnish and an enamel ?

(b) How would you proceed to paint (i) a new wood panelled door, (ii) a new steel roof truss of a workshop ? (May 1952)

13. Mention the several components that make paint and explain the purpose of each with example. (Nov. 1963)

14. What are the different types of paints used for protecting steel structure in coastal region in India ? Write a short specification for the work of renovating the paint of gated structure of a spill dam. (Nov. 1963)

15. (a) Mention the various types of failure commonly abserved in a paint work and state how they are prevented.

(b) What preparatory work should be done before repainting an old painted surface. (Nov. 1966)

## Other Examination Questions

16. What is priming ? With what materials it is done in case of wood and iron ?

17. Describe the process of painting old and new work. What are the objects of painting and varnishing ? State where varnishing should be done in preference to painting.

18. In connection with paints explain the terms : (a) base, (b) vehicle (c) solvent, (d) drier, and (e) colouring pigment. In each case name a substance suitable for the purpose.

19. What are the general ingredients of oil paints and what is the object of each ? What precautions should be taken before painting (a) a new wood work and (b) a new iron work ?

20. Describe how you would paint an old work. What do you understand by covering power of a paint ?

21. What are the materials most commonly used in paints and varnishes ? Where and why these are used ? Explain their differences.

22. What are the substances from which are made base and vehicle in paint; what are the ingredients of copal varnish ?

23. If told to paint a house white both inside and outside, would you have any choice between the materials composing your paints ? If so, what would they be ?

24. What are the corrosion in iron and steel ? Name the essential properties of a good paint. Linseed oil is the usual vehicle for paints. Why is a mineral oil having the same appearance unsuitable although it would be cheaper ? What precaution must be observed before priming a steel girder ?

25. Give specification for red paint, green paint and white paint.

26. How are the following prepared and used—copal varnish, French polish and Japan?

27. A new iron shed and timber house are to be painted. Would you use paint of the same composition for both ? State your reasons.

28. What precautions are to be taken in applying paint ?

# *Chapter 7*

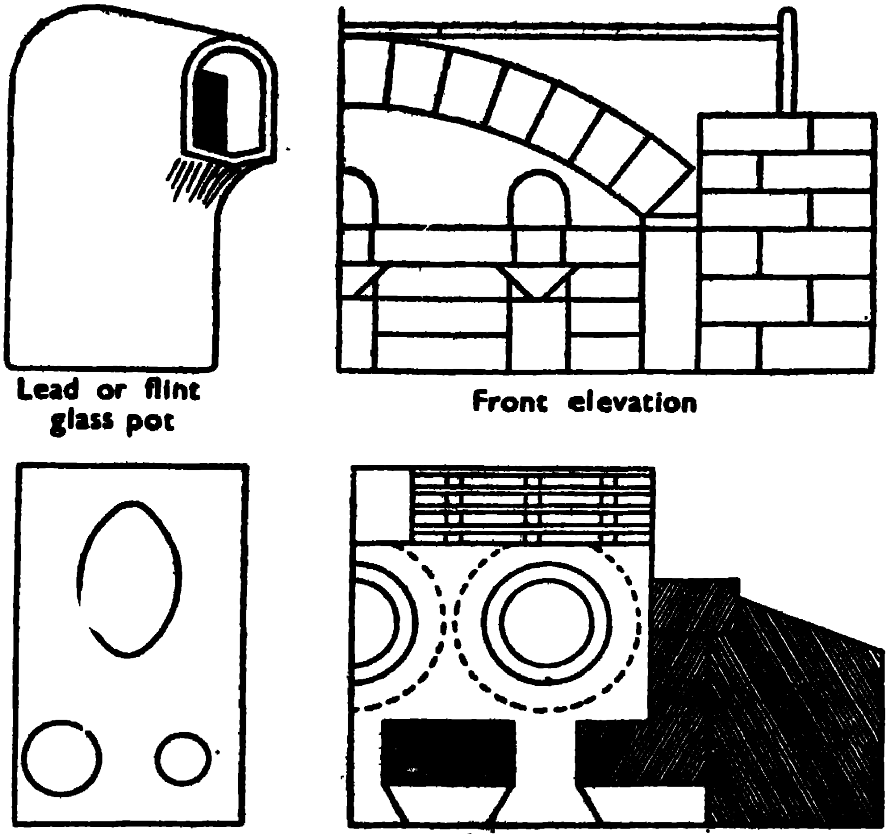
## MISCELLANEOUS

### 7.1 Glass

It is made by melting in *pots* (Fig. 7.1) of a *furnace* (Fig. 7.1) at a very high temperature a mixture of pure sand ($SiO_2$), soda ($NaOH$ or $KOH$) and chalk ($CaCO_3$) with some quantity of broken glass and then casting the molten mass into *moulds* (Fig. 7.1) of required shape. It is brought into convenient forms for use by different processes which need not be fully described here as an engineer is never called upon to make glass for himself. Fabrication of commercial goods is done in five different ways: (1) Blowing, (2) Flat drawing, (3) Rolling, (4) Pressing into moulds, and (5) Spinning. It is transparent and so hard that it has to be cut with a diamond edge. The cost of glass panes is not proportional to their sizes. Large size panes are very costly due to the difficulty in manufacture and preserving. It is largely used for glazing, framing pictures, making bottles and household wares but used also for looking glass, lenses, roofing and walling in special cases.

#### 7.1.1 *Composition of Glass.*

| Type of glass | Percentage of constituents | | | | | |
|---|---|---|---|---|---|---|
| | Silica | Lime | Soda | Alumina | Red Lead | Potash |
| Ordinary glass, Window glass and Plate glass | 70 to 75 | 10 to 15 | 10 to 15 | 2 to 5 | .. | ... |
| High class glass, Special glass and Cut glass | 50 | . . | .. | ... | 35 | 15 |



Lead or flint glass pot

Front elevation

Moulding block

Quarter plan

Fig. 7.1 Glass furnace

Fig 7.2 Blow pipe

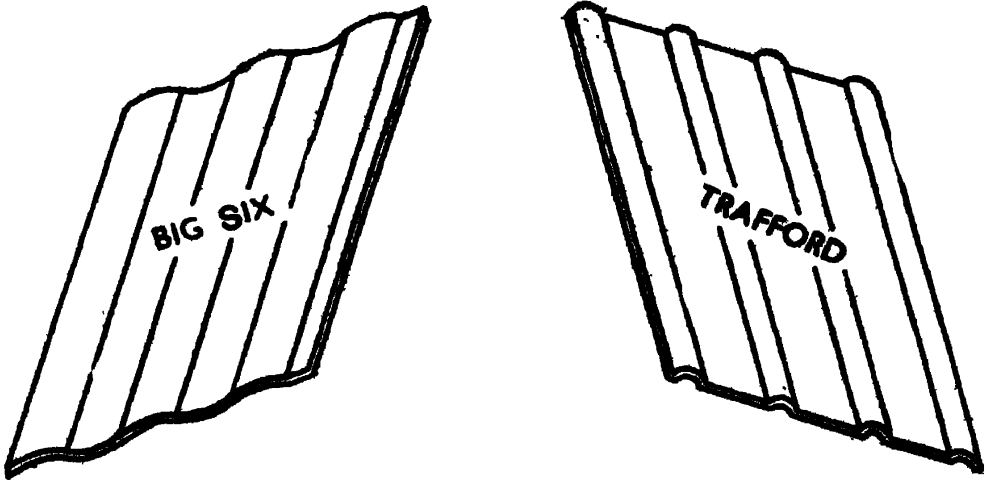


Fig 7.3 Asbestos sheets

### 7.1.2 *Different Kinds of Glass used for Engineering Purposes.*

*Crown glass* is practically obsolete. In its manufacture a *blow pipe* (Fig. 7·2), an iron tube 2 m long, is deeped into melted glass which is then blown into a globular form. The globe is then detached from the blow pipe, heated and rotated vigorously on a flat disc until flattens out. The glass is slightly convex. In cutting the plate into panes the central portion must be avoided and so there is a good deal of waste. Crown glass is superseded by sheet glass due to the demand for large sizes. Crown glass is free from colour and has a finer surface and so it is used for special articles.

*Sheet glass* is made by blowing molten glass into a large hollow cylinder, splitting the cylinder longitudinally and then flattening it over a disc. It is used for ordinary purposes.

*Plate glass* is made by pouring white hot glass over an iron table and rolling it to uniform thickness under heavy metal roller. It is stronger than sheet glass. It is used for looking glass and large paned glass for good houses.

*Perforated glass* is made by punching holes right through sheet glass by roller and so is used for ventilating pantries and others. Perforations are either made during manufacture or cut afterwards but latter is better.

*Fluted or ribbed glass* is of a wavy section with corrugations on both sides. It is used where it is required to secure privacy without obstruction of light.

*Wired glass* is a plate glass with wire netting embedded in it. It resists fire and does not fall into pieces when fractured. It is used for fire resisting doors and windows, skylights and roofs.

*Figured rolled glass* is a plate glass which is cast on a table under a roller with impression of desired pattern on the surface of the glass from the roller. It transmits light but object cannot be seen through it properly.

*Ground glass* or *obscured glass* is made either by grinding one side of glass or melting powdered glass upon it. This glass is used where light is required without transparency.

*Enamelled glass* is obscured in parts according to a design stencilled upon it. Enamel placed to from the pattern and then fluxed by heat.

*Coloured glass* is made in every variety of tint by adding metallic oxides and other substances to the materials before fusion.

*Glass tile* is made of sheet glass either plain or of shape to correspond with earthenware tiles so as to be worked with those in roofs for the admission of light.

*Calorex glass* eliminates heat without imparting light.

*Laminated glass.* Two or more sheet glass can be made into a sandwich with resin plastic between them. It is shock absorbent and provides a good acoustical medium.

*Annealed glass.* Glass is brittle when suddenly cooled but when it is cooled slowly under controlled condition in an annealing furnace it is called annealed glass and it resists heat changes.

*Glass wool* can be made by tempering and annealing for heat and sound insulation.

*Glass blocks* or *structural glasses* are made up of two halves fused together so as to form a hollow inside and are used for outside walls and partitions. Blocks are laid like bricks with a special mortar. Good transmission of light, ease of cleaning and insulation against heat, cold and sound are special advantages.

*Obscuring panes of glass.* Mix ·45 kg white lead with 113 g linseed oil and 28 g varnish till it becomes plastic. The mixture is put into a linen which forms a ball of 2·5 cm in diameter and then the ball is pressed against the glass with considerable pressure but it should not be rubbed.

*Glazing.* The glass as per specification cut to size by diamond cutter, free from blemishes, is to be set in good putty and secured by brads (small headless nails) whenever necessary. The .rebate is to be neatly chamfered. Linseed oil putty is to be used in wooden frames, metallic putty in iron frames and oil mastic is stone setting.

*Insulating glass.* It consists of two sheets of transparent glass into which a layer of dehydrated air 6 mm to 13 mm thick is hermitically sealed. On account of the air gap the apartment is kept cool in summer and warm in water.

*Bullet-proof glass.* This type of glass is extensively used in jewellery store, show cases, observation chamber and bank tellers. The glass is made from at least 4 layers of 2·5 cm to 5 cm thick glass sheets between which are sandwiched alternate layers of Hi test plastic. The cover layers are of glass sheet while the inside layers are alternatively glass and plastic.

*Glass blocks.* The use of glass blocks, made by fastening two halves of pressed glass are now extensively being used as non-load bearing walls, day light openings in the stair case and for decorative purposes. Though they do not carry any load, yet they can be had in heights upto 6 metres for purposes of supporting their own weight. They are manufacturers in 15 cm, 20 cm and 30 cm square sizes and 10 cm thickness. They may be set in cement mortar 1 : 2 or 1 : 1 : 4 composite mortar.

*Mirrors.* The otherwise transparent surface of clear glass is made reflecting by laying a layer of silver nitrate and ammonia on the back. This layer is protected from dampness with a top coat of tar paint. lead or shallac.

## 7.2 Resins

These are natural or synthetic substances which are soluble in some organic solvents and which when deposited from an adherant film. These are used in varnishes.

## 7.3 Glue

The waste parts of horns and hoofs of animals used for trade and other purposes are steeped in water. boiled, strained, melted, reboiled and cast into cakes. To prepare glue for use the cakes are broken up into pieces, soaked in water for 12 hours, melted and boiled in a glue pot and some boiling water is added to make it thin. It should be applied while hot and will be sticky when mixed with powdered chalk or saw-dust. Glue is chiefly used in joints between pieces of timber so as to stick to each other. *Adhesives* may be animal glues, starch glues and others.

7.3.1 *Animal Glues.* Animal bones, fish bones, butchers' refuse bones and various other types of bones are crushed to a fine powder and degreased. The degreased powder is treated with hydrochloric acid for a period which may vary from 2 to 12 depending upon the type of the bone. The adhesive prepared from animal glues is used in wood work. Another form of animal glue is the glue obtained after boiling hides and skins of animals in water and then drying the resulting liquid. Hide glue is also extensively used in furniture making and wood industry.

According to IS : 852—1957, animal glue is required to satisfy the following :

*Water absorption*

Grade I - 18 times the dry weight of glue

Grade II—15 times the dry weight of glue

Grade III—10 times the dry weight of glue.

7.3.2 *Casein Adhesive*. When skimmed milk is acted upon by some acid casein is obtained in the form of curd by the action of bacteria. When this powder is treated with dilute alkaline solution, a glue is formed. These glues form strong water proof wooden joints.

IS : 850-1957 lays down the following requirements for casein adhesive :

(i) *Wet mix glue*. It should wholly pass through IS sieve 60 when shaken in the sieve for 10 minutes.

(ii) *Dry mix glue*. It should pass through IS sieve 25.

7.3.3 *Starch Glue*. Starch glues are largely used in paper and textile industry. It is prepared by mixing rice or wheat flour with hot water and making a paste out of it. Small proportion of acid or alkali may be added to it to thicken the paste. These glues are easier to prepare but have poor water resistance as compared to animal glues.

7.3.4 *Gum Arabic*. Very extensively used all purpose glue obtained from acacia tree. Extensively used for packings. It is also used for labelling machines as well as for joining wood and paper.

7.3.5 *Albumin Glue*. Blood serum or white of an egg are used for the preparation of this type of glue. The particular quality prepared from dried blood is known as blood albumin. Such a glue is extensively used wood work, leather work and packages.

7.3.6 *Rubber Leased Adhesives*. Reclaimed material rubber adhesives have the advantage of low cost as they are mostly prepared from otherwise useless automobile tyres. Rubber cement is obtained by dissolving rubber in benzene and form excellent non-rigid bonds.

*Dextrine*. Available in yellow or white colours and prepared by treating starch with acid and heating to approximately 200°C. White dextrine is readily soluble in water whereas the yellow variety dissolves in water after heating. Generally used on wall paper and fast machine packing.

*Size* is made from the best glue, 4·5 lit of size is obtained from ·45 kg of glue. It is used in distemper to make the colour adhere to the surface.

## 7.4 Putty

Glazier's putty is made with whiting (finely powdered chalk) with raw linseed oil to form a stiff paste, well kneaded, left for 12 hours and then worked up in small quantities at a time until quite smooth. Mixture of white lead and putty in the proportion of 1 : 2 will be stronger. It is used in fixing glass panes. The putty may be softened to remove the glass panes by the following mixture applied on putty : One lb. of pearl ash is mixed with 3 lbs. of quick-lime slaked in water. Plasterer's putty is lime punning.

## 7.5 Petroleum

Petroleum occurs in porous sand stones below the surface strata and impervious rocks and is pumped out through bore holes sunk beneath the earth. The pumped oil is then led to the refinery through underground pipes leading to ports for facility of transport.

Crude petroleum is obtained as a dark coloured emulsion with sandy soil and water. This is warmed with steam coils whereby the emulsion breaks up into two layers. The gases evolved are led out by a pipe and mainly used as fuel. A portion of the gas is liquified. The upper layer of petroleum is removed and distilled into fractions of different boiling points to suit commercial purposes. The light and low boiling fractions are in great demand for automobiles. The kerosene fraction following it is purified by concentrated sulphuric acid, caustic soda and redistillation. The fraction remaining after the removal of kerosene is further separated with superheated steam to give the valuable *lubricating oil* and *paraffin-wax*. The solid thus obtained is decolorised with charcoal and is used for candle-making and waxed paper, in match industry and laundries, etc. The black residue left in the retorts is petroleum *pitch* used for road tarring.

The oil obtained after purification is the liquid paraffin used in medicine. *White oils*, which are refined lubricating oils, are used in making ointments, hair oils, etc. *White spirit*, the lighter fraction of the kerosene, is used for dry cleaning and paint vehicle, in shoe and furniture polishes, etc. Deodorised kerosene is used as hair tonic and antiseptics. *Grease* is a semi-solid lubricant composed of emulsified hydrocarbon oils and soda or lime soap with a little water as stabilizer.

*Fractional distillation of crude petroleum*

| Boiling point of the fractions | Name of fractions | Uses |
|---|---|---|
| Up to 30 degrees | Cymogene | In making ice, as fuel. |
| 31 to 70 ,, | Petroleum ether | For extraction of oils and fats. |
| 71 to 120 ,, | Petrol | As motor spirit fuel, for dry-cleaning. |
| 121 to 150 ,, | Benzine | For dry-cleaning as solvent and fuel. |
| 151 to 300 ,, | Kerosene | As illuminant, as fuel. |
| above 300 ,, | Lubricating oil or Diesel oil | As lubricant, oil fuel for Diesel engine. |

### 7.6 Bitumen and asphalt

Bitumen implies a group of hydrocarbons often mixed with some organic matter. It is known as petroleum in the fluid state, mineral tar in the semifluid state and asphalt in the solid state. *Natural asphalt* or *rock asphalt* is a bituminous limestone of rich brown colour which is largely used for roads and pavements. Natural asphalts are superior to artificial ones.

I.S. 334—1951 defines bitumen as a non-crystalline solid or viscous material having adhesive properties derived from petroleum either by natural or refinery process, substantially soluble in carbon disulphide.

*Artificial asphalt* or *mastic asphalt* is a preparation of natural asphalt, bitumen and sand. It is water proof, fire proof, easily applied and elastic to some extent. It is largely used as a damp proof course, water proof layer over flat roofs and makes a good non-absorbent floor for kitchen and latrines. Road paved with mastic asphalt is soft in summer and slippery in wet weather.

Bitumen softens easily by the rise of temperature and so it cannot be used on a surface where slope is more than 1 in 2.

There are two principal methods of applying asphalt to a surface :

(1) It is melted, spread and rubbed to a smooth surface e.g. floors.

(2) It is ground to a powder, spread and consolidated by ramming e.g. roads.

*Liquid asphalt* is obtained by carrying the distillation of asphaltic base crude oil to a temperature of 425°C. The viscus residue is called liquid asphalt.

*Cut-back asphalt* is produced by dissolving liquid asphalt in a small volatile solvent such as naphtha. It is applied cold as a bituminous paint or in repairing cracks in roof.

*Colas* is a type of asphaltic bitumen emulsion containing over 50% bitumen the balance being water and a small percentage of soap. It allows emulsion stable during storage but the bitumen separates out from water when it comes in contact with the road surface.

Bitumen has been classified into the grades according to I.S. 702 - 1961 as detailed below :

(i) 65/25
(ii) 75/15
(iii) 75/30
(iv) 85/25
(v) 85/40
(vi) 90/15
(vii) 105/30
(viii) 115/15
(ix) 135/10
(x) 156/6

The first figure gives softening point in degrees centigrade and the second figure gives penetration in $\frac{1}{100}$ cm at 25°C, 100 g, 5 sec.

According to I.S. 334—1953, asphalt is defined as a natural or artificial mixture in which bitumen is associated with inert mineral matter.

## 7.7 Asphaltic cements

Asphalt is oxidies when air is blown through it at high temperature and the resulting material is of a plastic nature and is highly resistant to climatic variations. It is useful for flooring, roofing and water-proofing purposes and also used in paints and expansion joints.

## 7.8 Fuels

The following fuels are used :

(a) *Solid fuels*, such as, coal, coke, etc. are burnt in air for production of heat.

(b) *Liquid fuels.* such as, petrol, fuel oils, etc. are used for locomotion and also for power generation.

(c) *Gaseous fuels*, such as, coal gas, producer gas, water gas, coke oven gas, blast furnace gas, sewage gas, etc. are used for heating, lighting, metallurgical purposes and also for running gas engines.

*Coal* is formed by the bacterial decomposition of the vegetable matter in presence of air and under great pressure of earth. It is a mineral substances of black or dark brown colour composed of the remains of plants and containing such proportions of carbon and hydrogen that it can be used as fuel. Coal is extracted by mining operation. Coal of different types are as follows :

1. *Peat.* It is the first stage of coal formation.
2. *Brown Coal.* It is intermediate between peat and coal. It has poor heating power.
3. *Common Coal.* It burns with luminous flame resembling that of bitumen. It is divided into coking and non-coking coal.
4. *Cannel Coal.* It is used exclusively for gas-making. It gives little coke.
5. *Smokeless Coal.* It burns without smoke but with intense heat and produces little ash.
6. *Steam Coal.* It is free burning non-coking coal.

*Calorific value* of coal is measured by its *calorific power* i.e. number of calories of heat produced when 1 gram of the fuel is completely burnt in oxygen. Coal is used as fuel and it is also used in the manufacture of *coal gas* during which *coke*, *gas carbon*, *coal-tar*, etc. are obtained as by-products.

Carbon and hydrogen are the two combustible constituents of fuel. Oxygen in a fuel does not give calories but diminishes the calorific value of hydrogen present. 8 parts of oxygen neutralises 1 part of hydrogen by weight. 1 gram of carbon yields 8,100 and 1 gram of hydrogen yields 34,500 calories of heat. If C, H and O are respective weights of carbon, hydrogen and oxygen in 1 gram weight of fuel then the calorific value of fuel in calories per gram $= 8{,}100\,C + 34{,}500\left(H - \frac{O}{8}\right)$.

The composition of a fuel is as follows : $C = 50\%$, $H = 18\%$ and

O=32%. Then calorific value $=8{,}100\ C+34{,}500\left(H-\frac{O}{8}\right)=8{,}1000\times$ $\cdot50+34{,}500\left(\cdot18-\frac{\cdot32}{8}\right)=8{,}880$ calories per gram.

*Coke* is obtained by heating powdered coal in *coke-ovens* and quenching the mass with cold water. There are hard coke, soft coke, metallurgical coke, foundry coke, etc. Coke is used as fuel and also as reducing agent in metallurgy.

*Gas Carbon* is obtained as a hard deposit inside the upper part of the retort during the manufacture of coal-gas. It is a good conductor of heat and electricity. It is used in electric batteries and in arc-lights.

*Petrol* is obtained by the fractional distillation of crude petroleum as a boiling point of 70°C to 120°C. It is used as motor spirit fuel and for dry-cleaning.

*Diesel Oils* are petroleum distillates obtained after kerosene. Flash point is 73°C.

*Coal-Gas.* It is a mixture of several gases viz. Hydrogen, Marsh gas, Carbon-monoxide, Ethylene, Nitrogen, Carbon-dioxide, Oxygen, etc. and is obtained by the destructive distillation of coal in fire-clay retorts. The products of distillation of coal are :

(1) Coal-tar used for preserving timber,
(2) Gas-liquor used for liquor ammonia,
(3) Coal-gas used for illuminating purposes and as fuel, and
(4) Coke used as fuel and in metallurgy.

The residue left after the distillation of the coal-tar is called *pitch* which when treated with tar oil, gives *asphalt* which is used for paving roads, making varnishes, etc.

The average composition of the coal-gas is as follows :

| | | |
|---|---|---|
| Hydrogen | ... | 45—50 per cent |
| Marsh gas | ... | 25—35 ,, ,, |
| Carbon monoxide | . . | 5—10 ,, ,, |
| Ethylene, Benzine, etc. | ... | 2— 5 ,, ,, |
| Nitrogen | ... | 2—10 ,, ,, |
| Carbon-dioxide | ... | 0— 3 ,, ,, |
| Oxygen | ... | 0— 2 ,, ,, |

*Water Gas.* Steam is decomposed when it is passed over white-hot coke, giving a mixture of CO, Hydrogen and a little $CO_2$. This mixture is called water-gas.

$$C + H_2O = CO + H_2. \qquad C + 2H_2O = CO_2 + 2H_2.$$

Water gas has a high calorific value. It is used as a fuel and in the manufacture of Hydrogen.

*Producer Gas.* It is produced by passing a regulated supply of air through a stack of red-hot coke. It is a mixture of CO and Nitrogen and is used as a cheap industrial fuel and as a reducing agent. It is much used in working gas engines.

$$C + O_2 = CO_2. \qquad CO_2 + C = 2\,CO.$$

*Oil Gas.* It is prepared by dropping crude oil, sometimes kerosene oil, in retorts heated to bright redness. The complex hydrocarbons, which form the oil, break up at the high temperature yielding a number of simple gaseous hydro-carbons. The gases are cooled and then stored up in gas holders. It is used in Moffusil towns where the supply of coal gas is not found possible.

Gases are also obtained from blast furnace and coke ovens. 0·5 c. ft. *or* 0·015 $m^3$ of *sewage gas* is produced per capita per day. It contains 65% methane, 30% $CO_2$ and 5% $H_2S$, CO, N, H, O, etc. Its heat value is generally due to methane.

## 7.9 Tar and its products

Tar is a dark black viscous liquid. It is divided into three classes according to its sources :

1. Coal-tar,
2. Wood tar, and
3. Mineral tar.

1. *Coal-tar* is produced by heating coal in a closed iron vessel and it is deposited in tubes kept cool by the circulation of water. It is a by-product in the manufacture of coal gas. When it is distilled, by-products such as *coal naphtha* used for dissolving India rubber, *creosote oil* used for preserving timber, and lastly *pitch* used for asphalt are obtained. Coal-tar is used for preserving timber and also making tar macadam roads.

2. *Wood tar* is obtained by the distillation of pine and other resinous trees. It has strong preservative qualities owing to the presence of creosote oil in it. The residue left after distillation is *pitch*. Pitch is a bright black solid but brittle. It is used in roads and pavements as inferior substitute of asphalt.

3. *Mineral tar* is obtained by distilling bituminous shales.

## 7.10 Turpentine

It is the oleo-resin exuding from any coniferous tree. Oil of turpentine is obtained by distilling with water turpentine previously melted and strained. It is colourless, very fluid and of a peculiar smell. Oil or spirit of turpentine is used in paint as solvent.

## 7.11 Knotting

It is the material used by painter to cover knots in wood, with an object of preventing exudation of resin from knots and thus to prevent knots from absorbing paints and leaving marks on the painted surface. This is done in the following three ways :

1. *Size knotting* is made by grinding red lead in water and mixing with strong glue size and applied hot. The second coat is of red lead ground in oil and thinned with boiled oil or turpentine.

2. *Patent knotting* is made by dissolving shellac in methylated spirit.

3. *Lime knotting* is made when knots are covered with hot lime and scraped off. Then the surface is coated with size knotting.

## 7.12 Cellulose

It is the white fibrous substance, which forms the cell walls of plans. Its chief sources are wood, cotton, hemp, jute, etc. From cellulose compounds are made paper, rayon, etc which are widely used in wrapping packages. *Celluloid* is a thermoplastic made from nitro-cellulose, camphor and alcohol. It is used for set squares, protectors, fountain pens and toilet articles.

## 7.13 Wall and ceiling papers

Buildings are seldom papered with paste in India except in dwelling houses in hills. Dry plastered walls and ceilings are sometimes covered with papers with ornamental designs printed or painted on them. These papers are not at all suitable in a damp climate like that of Bengal and in parts infested with white ants. These papers are generally imported in India from foreign countries. Wall papers are sold in pieces and borders are sold by yard or metre. These papers are of three classes :

1. *Common* or *pulp paper* has the ground of the natural colour of the paper and some pattern is printed on it.

2. *Satin paper* has a bright polished surface resembling satin. It is made by printing the paper with colours and polished with French chalk powder. It is affected by damp and so should

be carefully laid on dry walls, over a lining of ordinary paper. It can be kept clean for a long time as dust and dirt will not easily collect on its polished surface.

3. *Flock paper* has the pattern first printed in size and then in varnish. Cork dust or flock from woollen cloth is sprinkled over the pattern which adheres to the varnish to form the actual pattern. It is beautiful but catches dust.

### 7.14 Paste

It is made in different degree of strength according to the weight and thickness of the paper to be hung with it. Good white sifted wheat flour is beaten up in cold water to form a stiff butter taking care to get rid of all lumps and then pour boiling water over the butter stirring rapidly. Paste is ready when the mixture sweels and looses the white colour. Its strength is increased by the addition of a little alum. Glue paste is liable to go hard when cold and so when used, it should be used hot and kept well stirred.

### 7.15 Asbestos

It is a fire proof and acid proof natural fibrous mineral substance of different colours. It is a silicate of calcium and magnesium. It is used in steam pipe joints and in the manufacture of fire proof roofing and flooring materials owing to its fire resisting property.

*Italit* or *asbestos cement sheet* (Fig. 7·3) is made of a mixture of asbestos fibre and portland cement, which is pressed into thin plain or corrugated sheet. It is used for roofing and walling of important buildings as it is heat, weather and rust proof. It is more economical than iron sheet. Rain water pipes, gutters ventilators, flues, etc. are also made of asbestos-cement

### 7.16 Fibres and felt

Fibres may be inorganic and organic. These may be natural or synthetic. These are used for packing and also for making fabric and felts.

*Glass wool* and *lead wool* are synthetic mineral fibres.

*Glass wool* is made as fine fibres of dia. ·025 mm. It is used as packing for heat, sound and electric insulation and also for making fire proof and acid resistant fabric.

*Lead wool* is lead in fibrous form and used in water pipe joints in moist situation where molten lead cannot be used.

*Rayons* and *nylon* are organic synthetic fibres.

*Burlap* is a coarse jute or hemp.

*Hessian* is a jute fabric.

*Felt* is useful to engineers when saturated with asphalt, bitumen, and other substances.

*Asphalted roofing felt* is used as roof covering for temporary sheds.

*Bitumen felt* is used for damp walls, floors to deaden sound, and bedding girders, columns and heavy structures.

*Hair felt* is used for preventing the escape of heat from boilers and pipes.

### 7.17 Rust cement or cast iron cement

It is composed of a mixture of cast iron turnings passing through a sieve of eight meshes to the inch, powdered salammoniac and sometimes flour of sulphur. Generally 28 gm of salammoniac to 50 kg of iron turnings are used. It is used to make the joints of cast iron tanks and pipes water-tight.

*Oil cement* consists of 5 kg of slaked lime and 1 kg of linseed oil by weight pounded to a thin paste for use in laying earthenware pipes.

*Wood cement* is a mixture of magnesium chloride, powdered magnesia and wood saw-dust. It is used in plastic condition like portland cement. It is non-inflammable. When mixed with cement it is used like patent stone for floors, staircase platforms to resist wear and tear.

### 7.18 Abrasives

These are used to polish by abrasion or grinding various metallic and other surfaces. Common abrasives used in industries are classified as (1) hard, (2) soft, (3) silicious, and (4) artificial.

Hard abrasives are diamond, emery, corundum and garnet. Soft abrasives are metallic oxides, rotten stone and lime. Silicious abrasives are quartz, flint, quartzite, sandstone and pumice. The common artificial abrasives are silicon carbide, fused aluminium oxide, steel shots and crushed steel.

*Grinding wheel.* The bond used in making grind wheels may be silicate, shellac, synthetic resin and rubber. Synthetic resins are superior to shellac as bonding material. Grinding wheel made with synthetic resins can be operated at high speed. Rubber bonded wheels are also operated at high speeds. It is used to polish by grinding various metallic and other surfaces. *Emery* wheel is grinding wheel where emery powder held on the surface of wheel forms the abrasive grain.

*Grinding paste* is made with some abrasive in powder form say emery made into paste with water or oil.

### 7.19 Emery cloth and emery paper

These consists of ground emery of different degree of fineness attached to calico and paper by glue. Emery paper is not much used but emery cloth is used for finishing and polishing metal surfaces.

*Glass cloth* and *glass paper* consist of ground glass of different degree of fineness coated on calico and paper respectively for polishing wood surfaces or rubbing down painted surfaces. Glass paper is mostly used.

### 7.20 Lath

It is used for plastering and for roofs to support coveting of tiles or slates.

*Plasterer's lath* is a thin strip of wood 2.5 cm wide and about 1 metre long but its thickness vary to suit the work for which it is meant.

*Tiling or slate lath* or *batton* is generally sawn out of boards about 3 metre long but its section varies from 2.5 cm × 2.5 cm to 7.5 cm × 2.5 cm.

### 7.21 Cork products

Cork is ground, sized, cleaned and baked in moulds. The natural resin in the cork comes out during baking and is useful in binding the materials. It can be used as flexible sheets or elastic boards. It is heat proof.

It is extensively used in cold storage construction and also for flat roof insulation. It is also available in the market in the form of bitumen—bound state.

### 7.22 Gasket

It is the jointing or packing material, such as, cotton rope impregnated with grease or oil. Flat sheets of asbestos compound used for making gas-tight joint and hemp, cotton or jute yarn used for packing joints in water and sewer pipes are also called gasket.

### 7.23 Rubber

It is of two kinds : 1. Natural and 2. Synthetic. Natural rubber is obtained from rubber trees which grow in hot moist climate, such as, Ceylon, Malaya, Singapore and Africa. The milky juice is collected from the tree every morning and is then coagulated by the addition of weak acetic acid. Water is then removed and the mass rolled into sheets. *Vulcanised India rubber* is obtained by mixing 44% of zinc oxide and 4% of sulphur to India rubber and it is chiefly used for pipe joints and valves. *Synthetic rubber* is produced artificially from acetylene gas. This is resistant to acids, grease, kerosene and petroleum. Rubber can be reclaimed from old worn-out articles by mechanical or chemical process. Rubber blocks are used for road surfacing as wood blocks but their use is now restricted due to the treacherous surface presented in wet weather. Natural rubber containing carbon black and vulcanized as for automobile tyres has a tensile strength of 350 kg/cm$^2$ and an elongation of 700% before rupture.

The properties of rubber are modified by mixing various ingredients with rubber in plastic form. The process by which this operation is carried out is known as compounding.

If the plasticity of crude rubber is reduced at the same time maintaining its elasticity by addition of material such as sulphur, the resulting product is a vulcanate, and is used for vulcanisation.

Crude rubber is softened by the addition of vegetable oil, waxes etc. These materials are known as a plasticiser.

If the property of vulcanate is improved in respect of the time required for vulcanisation by addition of materials like lime, magnesia, white lead etc, these materials are known as accelerators. Materials added to crude rubber with a view to improve. The resistance against weathering action of heat, light and harmful salts, such materials are known as anti-oxidants, the examples of which are phenols, amines and waxes.

The properties of crude rubber are also modified by the addition of colouring materials, reinforcing or fillers. Addition of magnesium carbonate, barium sulphate and calcium carbonate is made to increase the tensile strength of rubber and are therefore reinforcing agents. Lead chromate (yellow colour), ferric oxide (red colour) and lithopone (white colour) are used for colouring purposes and hence are known as colouring agents. Materials, which are comparatively cheap and are added with a view to reduce the cost are called fillers. Zinc oxide and carbon black are both fillers as well as reinforcing agents.

*Uses of rubber* : The following are some of the uses of rubber :

(a) Hose pipes, printing rollers and upholstry
(b) Mounting material
(c) Gasketing material
(d) Belting of all types
(e) Tyres and tubes
(f) As a buffer
(g) Lining for reservoir
(h) Rain wear and flexible tubing
(i) Adhesive
(j) Thermal insulation.

### 7.24 Belts

These are used for driving machinery from shafts or in making mechanical conveyors. The common materials used are leather, cotton, hair, canvas, rubber and balata.

*Leather belting* is made from leather cut from the portion of hide in the back of the shoulders and close to the backbone. It is cut into strips and is either vegetable-tanned or crome-tanned. Good leather belt must not stretch more than 15% and tensile stress of 175 kg/cm$^2$. Leather belt should not be allowed to get dry and brittle.

*Rubber belt* has better grip on pulley than leather belt and resists deterioration by moisture. *Balata belting* is canvas belting impregnated with balata gum, which is water proof and are not affected by oil or grease.

### 7.25 Gutta-percha

It is obtained from exudation of a species of trees growing in Malaya. The constituent of gutta-percha is an unsaturated hydrocarbon of colloidal nature, which becomes plastic when warm and tough and hard when cold. It is superior to rubber in its insulating property.

### 7.26 Mica and mica products

Good mica is the muscovite variety found in abundance in this country and is used for insulating purposes. The thin laminae are glued together by means of varnishes to form sheets. It has a high dielectric strength.

### 7.27 Plastics

Plastic is an organic material prepared form resin (natural or synthetic) with or without fillers, plasticizers, solvents or pigments. Wax, shellac, pitch, bitumen, etc. are natural resins. Plastic is capable of being moulded into shape under heat and pressure. There are generally two types of plastics : 1. Thermo-setting, and 2. Thermoplastic. Thermo-setting variety requires a great pressure and a momentary heated condition during shaping for subsequent hardening. In this process chemical reaction takes place, which is not reversible. *Bakelite* is an example of this plastic and its scrap is not reusable. In thermoplastic variety the process of softening by heat and hardening when cooled down could be repeated indefinitely. *Cellulose* and *shellac* are the principal varieties of this type and the scrap is reusable.

*Advantages of plastics* : (1) Resistance to climatic conditions and rots ; (2) Shock absorbing ; (3) Available in any colour ; (4) Permanent decoration ; (5) Can be sawn, punched and drilled like wood and also welded like steel ; (6) Glossy material as glass ; (7) Good electrical insulators : (8) Light material ; (9) Low thermal conductivity ; (10) Higher coefficient of expansion under heat.

There are various means for fabricating plastic articles depending on the nature of resin, size, shape, thickness, strength and other properties required. These are moulding, casting extrusion and lamination.

Fibrous materials, such as, paper, canvas, asbestos, etc. can be saturated and impregnated with a synthetic resin and also compressed together with heat to prepare hard and strong sheets. The sheets are bonded to one another. These are light, strong, impervious to water and oil, resistant to wear, acids and alkalies and have a high dielectric constant. These are largely used for electrical insulation, for making silent gears, pulley, wheels, water lubricated bearings and press tools.

Plastic can be given a metal coating either by electroplating or metal spraying.

The various ways in which plastic is used as a building material are given below.

1. *Flooring* :

Floorings may be poly-vinyl or thermoplastic. The poly-vinyl floors may be chloride type or acetate type. The poly-vinyl chloride type sheets are snowwhite and brittle but softens on being heated. These rubber type material forms the main ingredient of PVC floor finishes. On the basis of their appearance these chloride sheets may be further divided into

(1) *PVC sheet and tile* : formed by heating the ingredients and forming into sheets by passing between rollers. These can be had into different shades and colours. The normal thickness of the sheets is 1 mm but sheets upto 3 mm thickness are also available.

(2) *Fabric backed PVC sheet and tiles* : These are manufactured from PVC, fillers and pigments which, when hot are given a hessian backing. These sheets are useful for foot traffic but should not be subjected to wet condition.

(3) *Thermoplastic vinyl tiles* : These sheets are useful for laying on all types of flooring except on wet surfaces as they can take up the shape of the surface on which they are placed. These are prepared by heating plasticised PVC, asbestos and pigments.

The Polyvinyl Acetate Tiles are laid by spreading PVA emulsion filler along with suitable pigment. On drying this forms a tough layer. They are jointless as they are spread on the surface in an emulsion form. They present a comfortable and non-slippery surface.

*Plastics for heat insulation.* Foamed polystyrene, which is available in the form of light weight slab with low thermal conductivity is eminently suited for thermal insulation. These slabs can be readily fixed to the walls and can also be plastered.

*Plastic for roofing.* Phenolic-resin-bonded paper laminates are available in the market in the form of corrugated sheets. In addition to lightness these sheets have higher strength and better corrosion resisting property.

*Plastic load bearing members.* The use of plastic as load bearing members has not been developed as yet on account of softening effect of heat and the brittle fracture. However, in the U.S.A. composite plastic members consisting of foamed plastic core placed between reinforced glass polyester resin have been used with success in single storey buildings.

*Plastic piping.* Polythene has been extensively used as plastic piping material. Its lightness and flexibility has made this type of piping very popular.

Thermoplastic sheets have been used for rectangular and circular ducts. These ducts are however not suitable at or near the boiling point of water.

*Packing materials.* These are used for packing into joints or between surfaces of machine parts in contact. These are asbestos, cork, gasket, glass wool, hessian, lead wool, rubber, etc.

## 7.28 Gold leaf

It is used for gilding so as to ornament the mouldings of joinery or decorating walls and ceilings. There are several different tints of gold leaf.

## 7.29 Ropes

These are of following varieties depending on materials used · (a) steel wire rope, (b) manilla rope, (c) hemp rope, (d) coir rope, and (e) jute rope.

Manilla rope is pliable but wire rope must not be coiled or uncoiled like manilla rope. Steel wire rope and manilla rope are used where great strength is required. Manilla rope is also used as tug-of-war rope and in making rope ladder. Hemp rope is commonly used and is of some strength. Coir rope is used in scaffolding. Jute rope lasts for a short time and is used where practically no strength is required.

## 7.30 Nails, screws bolts and rivets

*Nails* (Fig 7.4)—There are many varieties of nails and in carpentry joints these are to be driven in incline so as to prevent them from coming out.

*Cast nails* are made by running molten iron into moulds. These are brittle and inferior in strength. These are cheap and used for lathing. These should not be used by masons and carpenters.

*Malleable nails* are cast nails made malleable.

*Hand wrought nails* are forged by manual labour. These are tougher and stronger than other nails but more expensive.

*Cut nails* are cut by machinery out of sheets of iron.

*Patent machine-wrought nails* are made of wrought iron pressed while red hot into shape by grooved rollers, then cut and heads formed by die.

7.30.1 *Varieties of Nails in Common Use.* ***Rose nails*** (Fig 7.4a) are either wrought, cut or pressed. These have chisel points and are driven into wood with flat point along grains for preventing splitting and hold faster. These are also driven in walls for hanging picture frames, putting up brackets, etc.

***Clasp nails*** are used by carpenter in soft wood where nails are to be clenched.

***Cut clasps*** (Fig 7.4b) are used for fixing rafters, ceilings, joists, architraves, linings and other joinery.

***Brads*** (Fig. 7.4c) are flat sided nails driven with flat sides parallel to grains of wood. Larger sizes are used for flooring and smaller ones for fixing mouldings and beads.

***Glaziers' brads*** are used fer securing large panes of glass.

***Clout nails*** (Fig. 7.4d) are used for fastening sheet metal, felt, etc.

***Counter sunk clouts*** (Fig. 7.4e) are used for securing iron plates to wood work.

***Spikes*** are used for nailing heavy work, such as, wood bridges.

***Dog spikes*** (Fig 7.4f) are used for nailing heavy iron work. Flat footed rails are nailed to wooden sleepers by dog spikes.

***Clout tacks*** resemble clout nails. These are used for nailing light sheet metal.

***Wire nails*** (Fig 7.4g) are round or square in section. These are used for packing cases as they do not spilt the wood.

***Copper nails*** are of shapes similar to iron nails. These are used where latter is subjected to corrosion.

***Slating nails*** (Fig 7.4h) are used for securing tiles to roof.

***Steel nails*** are made from molten metal pressed in moulds. They are finer but dearer than ordinary nails.

***Lath nails*** are mostly used for oak lath.

***Pipe nails*** (Fig 7.4i) are of wrought iron and used for fixing stock pipes to brickwork.

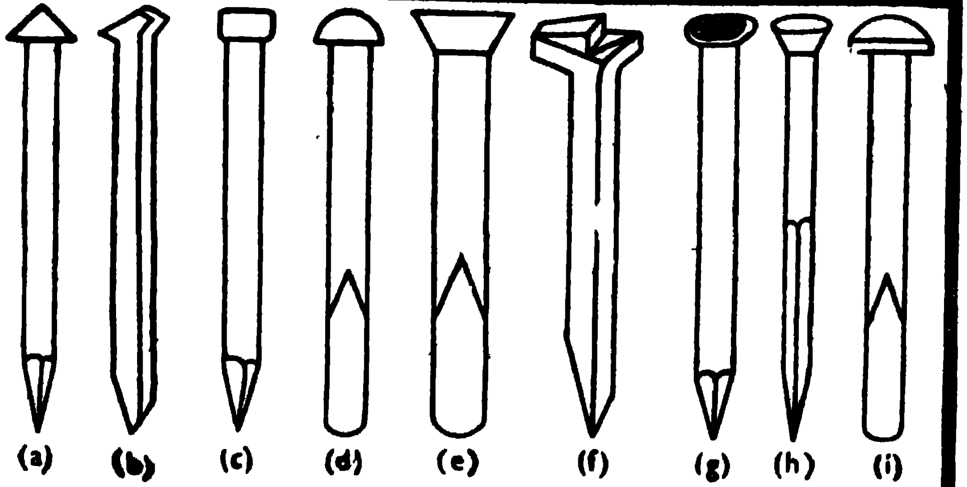


Fig. 7 4 Nails

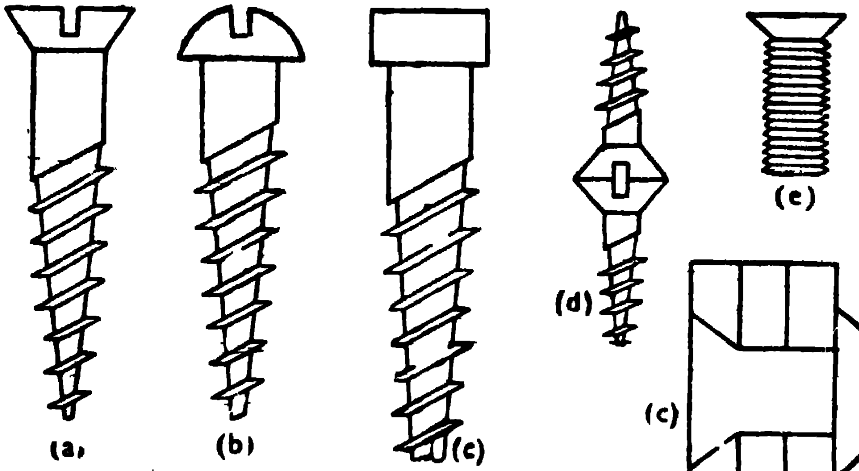
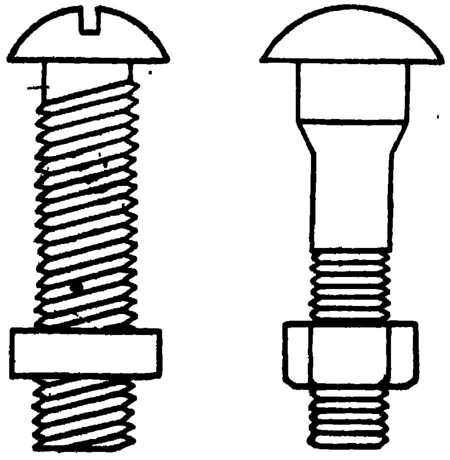


Fig 7.5 Screws



Fig' 7.6 Bolts

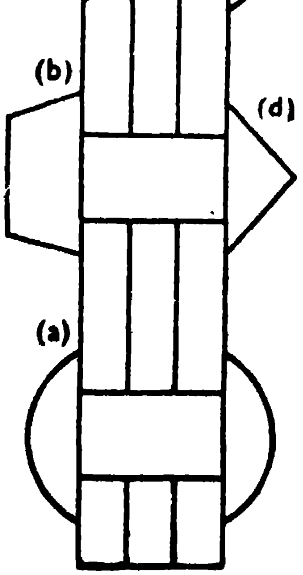


Fig. 7.7 Rivets

*Wood screws* are made of metal with sharp or levelled threads of different forms for screwing into wood.

*Flat headed* or *counter sunk screw* (Fig 7.5a) are used into wood for fixing all metal work so that top of the head is flush with the face of the metal to be screwed on.

*Round headed screws* (Fig 7.5b) are used where metal is too thin to be counter sunk.

*Nettlefold's patent screws* offer great resistance when tried to force out.

*Coach screws* (Fig. 7.5c) are used where great strength is required.

*Dowel screws* (Fig 7.5d) are forms of hand rail screws.

*Screws for metal* are made in different forms for wood screws. Diameter of screw is same throughout. Threads are V-shaped and close together.

*Stove screws* (Fig 7.5e) are small screws used for different parts of stoves, gate fronts, etc.

*Bolts* (Fig 7.6) are iron pins with a screw thread at one end and a head at the other and the fastening is completed by a nut. If $d$ be the diameter of bolt shank, then diameter of head $=2d$, depth of head $=\frac{3}{4}d$, diameter of nut $=2d$, depth of nut $=d$, diameter of washer $=3d$, and depth of washer $=\frac{3}{8}d$.

*Rivets* (Fig 7.7) are not so liable to become loose when subjected to wear as bolts and nuts and so are preferable for constructional works. Rivets are not generally greater than 2.5 cm in dia. but when one of greater dia. is required, bolts are used owing to difficulty of snapping up the heads. Rivets are of cup head (Fig 7.7a), pan head (Fig 7.7b), counter sunk head (Fig 7.7c) and conical head (Fig 7.7d). *Pitch* is the distance from the centre of one rivet head to the centre of the adjacent rivet head and it is generally 3 times the diameter of rivet.

## 7.31 Water

With the progress of civilisation the demand of water has increased considerably. The following are the various purposes for which public water supply is utilised and the quantity of water generally required for each purpose in India :

| *Uses* | *Quantity of water in litres per head per day* |
|---|---|
| 1. Household | |
| (a) Drink | 2.5 |
| (b) Cooking | 5.0 |
| (c) Ablution | 30.0 |
| (d) Utensil and house washing | 15.0 |
| (e) Washing clothes (laundry) | 15.0 |
| (f) Water closets | 30.0 |
| | 97.5 |
| 2. Municipal | |
| (a) Road watering | 7·0 |
| (b) Sewer flushing | 2·5 |
| (c) Fire prevention | 1.0 |
| (d) For baths, gardens and animals | 12.0 |
| | 22·5 |
| 3. Trade and manufacturing | 25·0 |
| | 145 |

7.31.1 *Purification of Water.* In considering the use of any water supply for domestic purpose there are two viewpoints apart from the question of the quantity available. Assuming the quantity is sufficient the next considerations are (1) can the supply be kept free from pollution ? (2) can the water be made suitable for domestic use at a reasonable cost ? Pollution of any supply may be due to surface water and the main possibilities are from agricultural land, sewage farm and road washings. Science has not made it possible to make any water perfectly suitable for drinking but there is a limit as regards the amount of treatment which can be carried out at an economical cost.

The main object of purification is to eliminate any traces of pollution that may give rise to disease. Suspended matter should be removed to make water clear and also dissolved mineral matter to render it soft. A public water-supply should be such as will not require further purification by its consumers. Impure water may be purified by either of the following methods :

1. *Natural* : (a) Storage, (b) Oxidation and Settlement.
2. *Artificial* : (a) Physical : 1. Distillation, 2. Boiling.
   (b) Chemical : 1. Precipitation, 2. Germicides.
   (c) Filtration : 1. Slow sand filter, 2. Mechanical filter.

The principal methods employed for the purification of water from the time of collection to the time it is released to service reservoirs on a large scale are : (1) Storage, (2) Filtration, and (3) Chemicals. Purification is satisfactory when germs of water-borne diseases are eliminated from water.

7.31.2 *Natural Purification of Water.* Nature helps to purify water. In streams and rivers purification takes place by sedimentation and dilution.

7.31.3 *Artificial Purification of Water.*

(a) **Physical methods :**

1. *Distillation.* Water is rendered pure in a chemical laboratory by converting the water into steam by boiling and then condensing the steam into water by cooling. 1 kg. of coal can distill about 15 kg. of sea water. It is not practicable on a large scale. Distilled water is ideal for boilers and washing. It is sold for use in chemical laboratories and in storage batteries.

2. *Boiling.* By this method some micro-organisms are destroyed and temporary hardness of water is removed. Boiled water is very insipid and so it should be aerated before drinking.

(b) **Chemical methods :**

1. *Use of precipitants.* By this method precipitates are formed which carries down suspended matters and micro-organisms.

2. *Alum.* This acts when water contains calcium carbonate. Its action depends upon the fact that alkaline carbonates combine with it and form aluminium hydrate. It forms precipitate which entangles suspended impurities and bacteria.

3. *Germicides.* The common germicides used to purify water are potassium permanganate, lime, copper sulphate, bleaching powder and ultra-violet rays.

Bleaching powder containing 20% chlorine will require ·5 kg lac litres. 35 gms is required for a well 1 metre diameter and containing about 3 m of water. A 15 m. sq tank requires about 7 kg of lime. Copper-sulphate is used in the proportion of ·1 to ·25 per 1,000,000 parts of water.

7.31.4 *Soft Water and Hard Water.* Soft water easily forms a lather with ordinary soap but hard water does not easily give a lather with soap. It does so after much soap is consumed.

Hard water contains calcium and magnesium salts in solution as carbonates, sulphates and chlorides. Hard water is not suitable for washing as it won't give any froth with soap, and is also unsuitable for cooking and in some industries. When hardness is due to carbonates of lime and magnesium in solution it is called *temporary*, as the hardness is removed by the removal of $CO_2$ by boiling and $CaCO_3$ is precipitated. $Ca(HCO_3)_2 = CaCO_3 + CO_2 + H_2O$. When hardness is due to the presence of sulphate and chlorides of calcium or magnesium and not removed by boiling, it is called *permanent*. It is not practicable to boil water on a large scale and this is done by adding 3 kg. of freshly found lime for every 1,00,000 gallons of water per degree of hardness.

$$Ca(HCO_3)_2 + CaO = 2\,CaCO_3 + H_2O$$
$$Mg(HCO_3)_2 + CaO = MgCO_3 + CaCO_3 + H_2O$$

This process of softening of water is known as Clark's process.

Permanent hardness is removed by converting the soluble sulphates and chlorides of Ca and Mg present into insoluble carbonates of Ca and Mg by addition of Sodium Carbonate (Washing Soda) to it.

$$CaCl_2 + Na_2CO_3 = CaCO_3 + 2NaCl$$
$$MgSO_4 + Na_2CO_3 = MgCO_3 + Na_2SO_4$$

*Hardness.* The standard of hardness is based on the weight in ·065 gms of calcium carbonate per 4·544 lit. As 4·544 lit. of water weighs 4,536 gms, it can be said that one degree of hardness is equivalent to 1 in 70,000.

Terms 'hard' and 'soft' water are used to indicate the quantity of mineral salts which are dissolved in the water. Underground water will be usually hard and overground water will be usually soft. While hard water is often preferred for drinking, it does not give forth with soap and so it must be treated if it is used in a laundry. It has the disadvantage as soap forms with hard water insoluble calcium and magnesium salts, which separate as a slimy curd very difficult to remove and moreover a waste of soap results. Hard water is also undesirable in dyeing and boilers. Engineer is faced with the deposition of carbonates causing boilers and pipes to be scaled periodically. This hard coating is a non-conductor of heat and so heat and coal are wasted. Moreover it reduces the size of pipe and chemical action of salts is detrimental to steel boilers and pipes. It shortens the life of boiler and pipe. When the fires are pushed, the boiler tube, separated from the water by the scale, may get heated to redness and expand away from the scale and if the scale gets cracked, the water coming in contact with the red hot metal, is suddenly converted into steam. This results an enormous pressure against the softened metal, which may suffice to burst the boiler causing considerable damage to life and property.

*Process of softening hard water.* In a tank of hard water proper proportion of milk of lime is added and stirred with mechanical stirrer and allowed to settle and the clear water is pumped out and then the tank is washed and the process is repeated. This is an *intermittent* system but there are water softeners where the system is *continuous.*

7.31.5 *Settling Reservoirs.* These are used to rid the water of most of its solid impurities in suspension. Their chief function is the separation and retention of the coarse silt. It is necessary to provide special settling tanks to catch the solid impurities before filtration when water is derived direct from rivers or streams. The number and size of these tanks depend on the quality and fineness of the silt in water when river is in flood. They may be intermittent or continuous flow settling tanks.

The greater the capacity of settling reservoirs the less the fatigue of filters. There must be at least two reservoirs to allow for cleaning. The standard depths for water of settling reservoirs are from 3 to 5 m. The form of a settling reservoir in plan will depend upon the plan of the land that may be available. A rectangle with the length in the direction in which the water flows, several times that of the breadth, is a good form from the point of efficient settlement and it will be an economical form where two or more reservoirs are constructed side by side. Efficiency of settlement ~~in~~ the reservoirs will depend on the manner in which the water is admitted to and drawn from reservoirs. Water, flowing in a direct line from inlet to outlet with considerable velocity should be avoided.

7.31.6 *Coagulation Tanks.* These are generally constructed in two parts viz. mixing chamber and settling chamber. Aluminium sulphate is added to the water to form the required film which will retain the fine particles and bacteria. Sodium sulphate is sometimes used along with aluminium sulphate in some cases. In the mixing chamber the coagulant is thoroughly mixed by keeping the raw water in constant motion by baffle plates, or by mechanical devices. These are generally used before mechanical filters and the velocity of flow is about ·75 m/min and the period of retention is 6 hours. These are usually 3 to 4 m deep and have pipe arrangements for removing the sludge intermittently. Inlet and outlet pipes are so arranged as to minimise eddies and currents as much as possible.

7.31.7 *Sand Filter or Slow Filter.* The work is carried out in large tanks rectangular in shape, level of top of tank at the natural land level, to remove suspended matter and bacteria. Rate of filtration is 3,000 lits per m$^2$ of sand surface per diam i.e. about 3 m in depth is filtered per diam and so the area of sand surface to filter a given quantity of water can be found out. As regards cleaning, carefully scrape off 2·5 cm thick sand from the top and then wash in sand washing plant. Then make the bed of ·6 m thick sand bed as before by properly washed sand. River sand is round and so not satisfactory. Sand must be washed though a certain quantity is lost thereby.

Sand is a mechanical strainer like filter paper. The bacteria organisms and injurious matters are in solution and very minute and so they pass through filter sand bed and cause fever. At the top of sand bed a thin bed of organic mat is formed which is the real filter and bacteria cannot pass through it. Even germs cannot pass through organic bed. Time is given to the bed to form a bed of mat before filtration water is examined for its bacterial organisms. Bacteriologist examines an unit quantity of water in bed and an unit quantity of water from outlet tap.

Maximum economical size is 3,000 m$^2$ of sand surface for cleaning and working. Clean water tank is covered. Filter bed themselves are not covered in but they are let to sun and air. Sometimes they are covered to prevent the freezing of water in cold countries. Filter bed may require cleaning after a week, fortnight or a month depending upon the kind of water filtered. This can only be gained by experience. Rate of filtration must be constant.

Filtering material is not only sand but also an organic scum at top of sand. When cleaned there is no scum at top of sand but run water slowly to form the scum. It takes a day or more to filter to its full capacity after the bed is cleaned. This scum or organic matter removes dangerous elements.

Practically the sewage of the town goes to river. River water must be thoroughly purified. In this case double filtration should be done—1st filtering through granulated oxide of iron or spongy iron and then through sand filters, where large area of land is required.

7.31.8 *Mechanical Filter or Rapid Filter.* It owes its origin from muddy river water. Ordinary sand filter is expensive and takes a long time because sand is soon clogged and hence the origin of mechanical filter. Mechanical filter is used to save time and labour and also to produce more or less equal filtering products. All objectionable germs are not deprived by such rapid process. There must not be more than 100 bacterial organism in a cubic centimeter of filtered water. This method gives clear water free from smell.

7.31.9 *Jewell Method.* It consists of a cylinder 5·5 m diameter carrying inside a sand bed 1 m resting upon gravel. Admitted water is to be filtered under great pressure to force water through the sand and water passes out through collecting drain. Washing takes place in a few minutes and it is done once or twice a day. The process is repeated by filtered water from bottom and mechanically stirred. Rate of filtration in this case is 30 times faster than ordinary sand filter. Here filtering material is same but rate of filtration is rapid and there is high pressure. Rate of filtration is 3,000 lits/$m^2$ of sand per diam in sand filter but 90,000 lits/$m^2$ of sand per diam in mechanical filter.

7.31.10 *Advantages of Rapid or Mechanical Filter.*

(1) Small area of land is necessary.

(2) Settling tanks are not required.

(3) Filtering material does not require changing and it is cleaned in a few minutes.

(4) Filtration is practically continuous.

(5) These are efficient and cheap. These are thoroughly adopted when cost of land is high and water is turbid.

7.31.11 *Deferrisation.* The use of ground-water for public water supply is becoming very popular owing to the success of the tube-wells in some parts of the country. In some cases they contain an objectionable amount of iron say .1 part or more in water per million, to be removed before being delivered to the consumers. Freshly drawn water containing iron is generally clear but gradually becomes turbid owing to the separation of brown precipitate formed by the action of air on iron in solution. This turbidity is not objectionable from hygienic point of view but the growth of iron becteria formed may block up pipes and takes a chalybeate taste and also becomes unsuitable for cooking, washing and other industries. Iron is generally present in the ferrous state but in some cases iron is held in solution by organic matter present in the water. The process of deferrisation or removal of iron from water is done by some special methods.

7.31.12 *Sterilisation.* Filtration gives more or less an efficient mechanical straining which often gives unsatisfactory result due to inefficient working or to accidents beyond human control. There are two methods of sterilisation viz : (1) physical method and (2) chemical method. In the physical method heat and light are employed for purification but this is very expensive and impracticable when large quantity of water is to be dealt with. In the chemical method oxidising chemicals, such as, caustic lime, permanganates etc. have been used from time to time for sterilising water. The agent now generally used is chlorine (a) in liquid form or as hypochlorite of lime or bleaching powder, (b) in the gaseous form and (c) as chloramine. Of the different compounds of chlorine mentioned above bleaching powder is mostly used. The amount required usually varies from ·15 to 1·5 parts of available chlorine per million.

7.31.13 *Boiler Feed Water. Scale* and *corrosion* must be guarded against in treating raw water for boiler feed. Water-softening methods are adopted to eliminate dissolved minerals causing boiler scales otherwise the scales in boiler result in higher fuel cost, low boiler efficiency and damage to boiler parts. *PH-value* of boiler feed water is kept between 9 and 11 to prevent corrosion in boiler.

7.31.14 *Water for Various Industries.* Soft water should be used for *laundries*, *wool* and *cotton mills*, etc. so as minimise wastage of soap. Clear water free from iron and manganese which stain paper, is used in *paper mills*. Soft water free from lime and iron, which stain and injure leather, is used for tanneries. Clean water free from sea and blackish water, which retards setting, is used for masonry and concrete-work.

7.31.15 *Analysis of Water.* Water is analysed to find out the suitability for various purposes and also as an aid in the control of purification prcoesses. It is analysed for its sanitary qualities in public water supply, for its mineral constituents, for the forms of micro-organisms and for qualities required for industrial processes. A sanitary analysis includes a physical, a chemical, a bacteriological and occasionally a microscopic examination of water.

### 7.32 Hume pipe

It is the patented R. C. C. pipe manufactured by Indian Hume Pipe Co. Ltd., Bombay. It is largely used in various sizes as street mains in water supply in place of C. I. pipes as it is light, cheap and durable.

### 7.33 Lubricants

These are used to diminish friction between two surfaces in motion relative to each other. Lubricants may be classed as *liquid and solid* lubricants as follows :

(1) Vegetable oils (olive oil, castor oil, nut oil, pum oil)

(2) Animal oils (whale oil, tallow oil, lard oil)

(3) Mineral oils (obtained from petroleum, coal tar)

(4) Blended oils (mixture of No. 3 with No. 1 or 2)

(5) Solid lubricants (graphite, soap stone).

*Grease* is a semi-solid lubricant and is used in the axle-boxes of Rly. rolling-stock. It is made from a mixture of palm oil and tallow and boiling it with washing soda solution.

The consistency of a lubricant depends on the nature, smoothness, speed and pressure on the parts to be lubricated.

Liquid lubricants are tested for (1) viscosity, (2) specific gravity, (3) flash point, (4) oiliness, (5) pour point, and (6) stability against oxidation.

*Lubricants for various purposes*

(1) For very great pressure with low speed—Graphite, soap stone.

(2) For great pressure with low speed—Lard, palm oil, grease.

(3) For heavy pressure and high speed—Palm oil, caster oil, medium mineral oil.

(4) For light pressure and high speed—olive oil, light mineral oil.

(5) Ordinary machinery--Lard oil, tallow oil, medium mineral oil.

(6) Steam cylinders—Lard oil, tallow oil, heavy mineral oil.

(7) For clocks and watches—Olive oil, hazet-nut oil, light mineral oil.

*Cutting fluids* are used during machining operations (turning, drilling, boring, milling gear-cutting, wire-drawing, tapping, threading, grinding, etc.) to serve the following purposes : (1) to keep cool the cutting tool, (2) to keep the work itself cool, (3) to keep down power consumption, (4) to provide good finish, (5) to wash away chips formed, (6) to prevent corrosion of work, and (7) to lubricate moving machine parts. For machining softer metals and alloys like copper, brass or mild steel either an emulsion or a sulphurized mineral oil is used but for machining aluminium, kerosene with 5% lard oil is used. For machining hard steel either an emulsion or mineral lard oil is used. For deep drawing operations on mild steel or aluminium sometimes a pure white soap mixed with water to a cream consistency is used. Evaporating lubricants are at present frequently used for deep drawing operations on light alloys. For machining plastics and hard rubber no coolant is necessary.

## 7.34 Refractories

These are non-metallic materials that can stand high temperatures. These are used in the construction or lining of furnaces, boilers, flues, converters, crucibles, dryers and pyrometer tubes. Refractories may be *acid*, *basic* and *neutral*.

Acid refractories (silica bricks, ganister) are used in lining furnaces in which the slag is acidic. Basic refractories (dolomite, bauxite) are used in lining furnaces in which the slag is basic. Neutral refractories (graphite, cromite) may be used in both the cases.

## 7.35 Heat insulators

Insulating materials are used for retarding transmission of heat and cold. The common materials are mineral wool, reflecting paper, cork, fibre-boards, asbestos cement sheeting, and hollow walls and tiles.

## 7.36 Sound insulators

Sound insulators or acoustic insulators are materials which offer resistance to transmission and reflection of sound. Heat insulators are also sound insulators. Fibre-boards, cellular concrete, acoustic plaster and quilt are good sound insulators.

## 7.37 Materials used in electrical engineering

These are classified into (a) *Conductor materials*, (b) *magnetic materials*, and (c) *insulating materials* or *insulators* or *dielectric*.

7.37.1 *Conductor Materials.* -*Electrical conductors* (cables, wires and filaments) are generally made from metals, metallic alloys or metalloids (carbon). The electrical conductance of a conductor is the reciprocal of its resistance. Specific resistance of materials increases with the rise in temperature.

**Metals**

ρ is the resistivity in microhms (μ-ohms) per $cm^3$ at 20°C and α is the temperature coefficient of resistance per degree C at 20°C.

*Aluminium* (ρ=2 9 μ-ohms, α=·0038) is used for high voltage transmission and bus-bars.

*Copper* (ρ=1·8 μ-ohms, α=·0038) is used for general transmission and wiring cables, windings of electrical machinery and as fuses in the form of strip.

*Iron* (ρ=10·0 μ-ohms, α=·0038) is used as cores of aluminium cables.

*Lead* (ρ=22·0 μ-ohms, α=·0038) is used in fuse wires.

*Mercury* (ρ=95·5 μ-ohms, α=·0007) is used for mercury arc rectifiers, switches and vapour lamps.

*Platinum* (ρ= 11·7 μ-ohms, α=·0039) is used for platinum resistance thermometers and thermocouples.

*Steel* (ρ=14·0 μ-ohms. α=·0048), copper welded or galvanised, is used for high voltage, long transmission spans and as 3rd rail for electric railways. *Steel* (hard drawn) is used in heavy duty electrical contacts.

*Tungsten* (ρ=5·6 μ-ohms, α=·0045) is used as filaments for electric lamps and electronic tubes.

*Zinc* (ρ=0·2 μ-ohms, α=·0040) as strip is used as fuses
*Silver* (ρ=1·59, α=·0038)
*Platinum* (ρ=10, α=·003)
*Mild steel* (ρ=19·9, α=·0048)
*Mercury* (ρ=95·783, α=·00089)
*Zinc* (ρ=5·8, α=·0037)

7.37.2 *Metallic Alloys.* Resistance alloys withstand 1000°C without oxidation and maintain mechanical properties satisfactorily.

*Brightray B* (ρ=1·1 μ-ohms, α=·0002) consists of Ni 59, Cr 16, Fe 25 and is used for electric irons and heaters.

*Brightray C* (ρ=40·0 μ-ohms, α =·0001) consists of Ni 80, Cr 20 and is used in making furnaces.

*Brightray F* ($\rho = 1{\cdot}1$ $\mu$-ohms, $\alpha = {\cdot}0003$) consists of Ni 37, Cr 18, Si 2, Fe 43 and is used for making furnace elements.

*Eureka* ($\rho = 49{\cdot}0$ $\mu$-ohms, $\alpha = {\cdot}0000$) consists of Ni 40, Cu 60 and ~~is~~ used for making starter and field regulator resistances and also wires for thermocouples and resistance boxes

*Manganin* ($\rho = 50$ $\mu$-ohms, $\alpha = {\cdot}000004$) consists of Cu-84, Mn-12, Ni-3·5 Fe-2. Most suitable for making precision resistances on account of its extremely low temperature coefficient resistance.

*German Silver* or Nickel Silver ($\rho = 30$, $\alpha = {\cdot}0003$) consists of Cu-63, Zn-12, Ni-15.

On account of development of more suitable alloys, its use has become ~~rare~~ now, earlier it was used in resistance boxes.

*Therlo* ($\rho = 45$, $\alpha = {\cdot}000005$)

Consists of Cu-71, Al-17, Mn-10, Fe-2.

It is used in making resistances and its resistance properties are similar to manganin.

7.37.3 *Semi Conductors. Carbon* ($\rho = 0{\cdot}001$ to $0{\cdot}005$ ohms, $\alpha = -0{\cdot}0002$ to $-0{\cdot}0007$) is used in making brushes of electrical machines, as arc lamp, contacts, electrodes, resistors, lamp filaments, valve anodes, etc.

Other materials used as semi-conductors are silicon ($\rho = 63600$) and germaniun ($\rho = 47$). Their conducting is midway between good conductors and good insulators and hence they are called semi-conductors. Their temperature coefficient of resistance is negative.

7.37.4 *Commonly used Conductors.* The commonly used conductors are (1) copper, (2) copper-cadmium alloy, (3) steel-cored aluminium and (4) copperweld ~~steel~~

*Copper* is used in making bus-bars ~~and~~ cables for overhead lines on account of its greater strength and stiffness. It has a high conductivity and is least subjected to corrosion.

*Copper-cadmium alloy* is used for overhead conductors on tram, trolley-bus routes and long span river crossings as it has 50% increased tensile strength.

*Steel-cored aluminium* is light and so it enables the length of span in overhead lines to be increased.

*Copperweld steel* is less costly and so it is used where economy in insulation is a chief consideration.

*Contact materials* are usually metals and alloys which are used for contact points or surfaces of electrical apparatus. Fine silver, coin silver, silver-copper alloy, nickel-brass, tungsten, silver-tungsten, silver-graphite, etc. are used as contact materials. Their qualities should be (1) high electrical conductivity, (2) high resistance to corrosion and (3) high resistance to wear. Carbon contact is provided in switches.

*Fuse wires* may be of tin, lead or tin-lead alloy for currents upto 30 amperes, and of copper or silver for currents above 30 amperes. Fuse wires are placed in non-inflammable insulating *fuse holders* made of porcelain. Fuses are used throughout electrical wiring and distribution systems. These are the simplest devices of protection against risk of damage or fire due to overloads as it is a conductor of comparatively fusible material. The fuse melts and breaks the connections whenever the current in the circuit exceeds the maximum current for which it is designed.

As fuse wire is required to melt and give way, at overloads, the wire is made from comparatively fusible material with melting point between 60° and 200°C. Upto 30 amps current lead and its alloy are used while copper alloy is used for high currents.

Wire fuses mentioned above are not suitable in case of high voltages. For this purpose high rupturing capacity fuses (HRC) are used. They are not likely to catch fire and do not deteriorate with time and can be used in situations where very high short current may be expected.

*Lamp filaments* may be of carbon (vapourising pt. 3,500°C), tantalum (melting pt. 2,800°C) and tungsten (melting pt. 3,400°C)

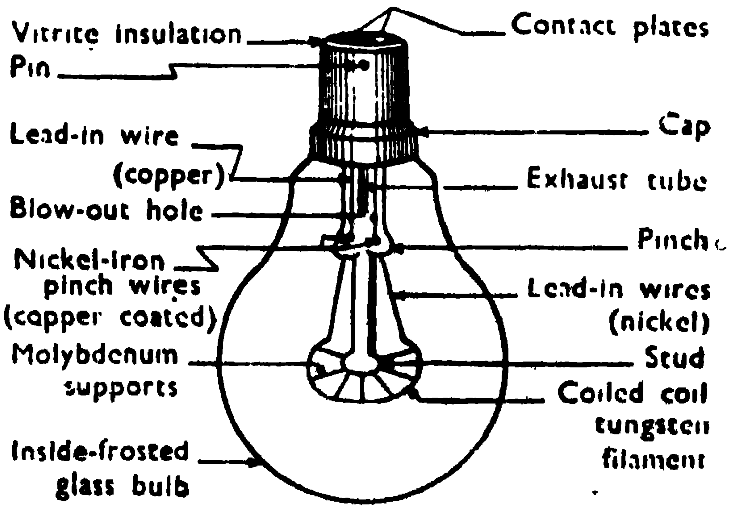


Fig. 7.7 Gas-filled incandescent lamp

Tungsten is now mostly used. Close coiled tungsten filament is coiled in the form of a circular arc and held in place by molybdenum supports to reduce the convection currents caused by the gas molecules in the bulb.

*Mercury vapour lamp* :

HPL fluorescent lamp consists of a quartz discharge tube, filled with liquid mercury and argon gas to facilitate starting, contained in a glass envelope, which on its inside carries a fluorescent phosphor powder. The space between the two bulbs is filled with an inert gas. Three electrodes are built into the discharge tube of the 80 W, 125 W and 1000 W type, two main electrodes and an auxiliary, the latter for ease of ignition only. In the case of the 250 W and 400 W type, however, Philips use four electrodes, two main electrodes and two auxiliaries in order to ensure the starting of these lamps with rather big discharge tubes even under very unfavourable conditions.

### 7.37.5 *Features*.

1. weather resistant outer bulb
2. high output in small dimensions
3. low open-circuit voltage
4. crisp white light
5. high luminous efficiency
6. perfect visual acuity
7. increased lumen maintenance

### 7.37.6 *Magnetic Materials*.

*Definitions*

*Unit magnetic pole* is a pole which experiences a force of repulsion of 1 dyne when placed at a distance of 1 cm. from a like pole.

*Magnetic force* (H) is the force exerted on a unit magnetic pole in vacuum in the direction of the lines of force (magnetic flux). It is measured in oersteds.

*Magnetic flux density* (B) is the normal magnetic flux *i.e.* the number of lines of force per unit area. It is measured in lines or megalines.

*Intensity of magnetisation* (I) of a body is the magnetic moment per $cm^3$ of the body.

*Magnetic field strength* (H) at a point is the force in dynes exerted on a unit magnetic pole placed at that point in vacuum.

*Permeability* ($\mu$) of a material is the ratio $\frac{B}{H}$. Permeability of air is unity.

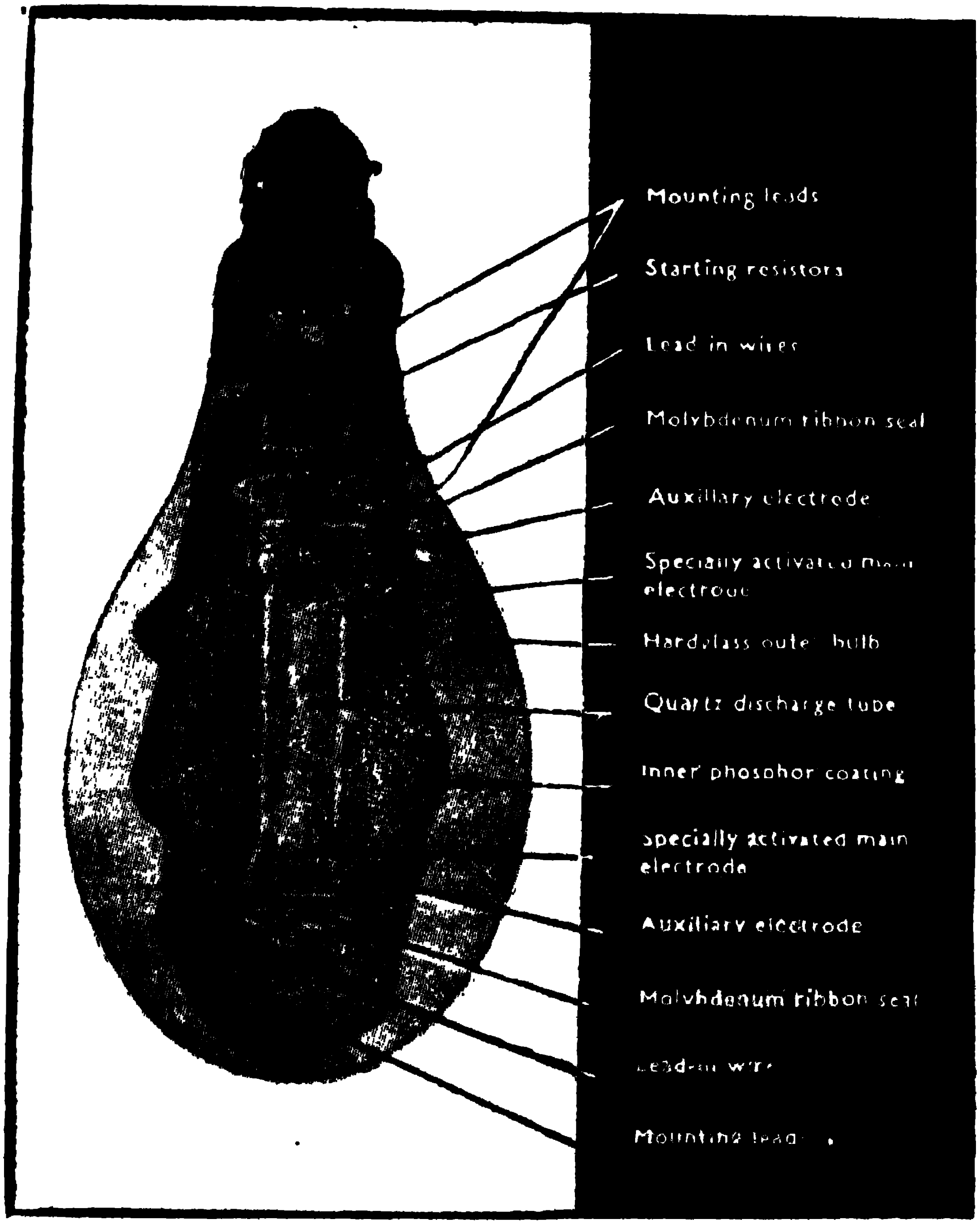


Fig. 7.8 Philips high pressure mercury vapour lamp

*(Courtesy of Philips India Limited)*

*Susceptibility* (K) of a material is the ratio $\frac{I}{H}$ in the magnetic circuit set up in the material.

*Magnetic reluctance* is the ratio which the magnetomotive force acting round a magnetic circuit bears to the flux produced. Reluctance is given by $l/a\mu$, where $l$=length of magnetic path, $a$=cross-section of path and $\mu$=permeability of material of the path.

*Ferromagnetic materials* have high magnetic properties and values of susceptibility and permeability are considerably greater than unity and are varying with flux-density. Iron, nickel, cobalt and some alloys are the only ferro-magnetic materials. *Paramagnetic material* has permeability slightly greater than 1. Paramagnetic substances are oxygen, platinum, etc. *Diamagnetic material* has permeability less than 1 and has a negative susceptibility. It is magnetised in opposite direction to that of magnetic field. Bismuth is diamagnetic.

*Coercive force* is the demagnetising force required to fully neutralise the residual magnetism in an electromagnet when the magnetising force is reduced to zero.

*Remanence* is the magnetic flux (B) still remaining in a magnetised material when the magnetising force is removed.

*Eddy-current loss*—Due to change in flux density internal electromotive forces are induced in the core of an electro-magnet, which set up locally circulating currents (eddy currents) and thereby there is loss of energy in the form of heat.

*Hysteresis loss* is the loss of energy that takes place in an electromagnet when it is subjected to cycles of magnetisation.

*Total core or iron loss* in a static transformer or an electromagnet is the sum of eddy-current or hysteresis losses.

7.37.7 *Magnetic materials.* These are (1) *Magnetically soft materials* and (2) *Magnetically hard materials.*

(1) *Magnetically soft materials* have high permeability and these are used in electrical machinery for poles of dynamos and cores of transformers and electro-magnets. Pure iron, cast iron, carbon steel, silicon steel and manganese and nickel steel are the more commercially used magnetically soft materials. *Pure iron* is unsuitable for alternating current. *Cast iron* is used in the framework of d. c. machine. *Carbon steel* is used in making fabricated structure. *Silicon steel* is suitable for a. c. and d. c. circuits. *Manganese and nickel steels* are used for making cable boxes, meter cases and end rings of turbo-alternators for

which non-ferrous metals are weak and magnetic materials are unsuitable. *Mumetal* (Cu 4, Cr 1·5%) is used for cores of current transformers, cores of wireless transformer and in moving-iron instruments. The properties of these materials are as given below:

*Cast iron* : Especially suitable for large D.C. machines as its frame becomes part of the magnetic circuit with constant flux. It is also used as framework for electrical machines but is unsuitable for alternating currents.

*Carbon steel* : The properties are similar to that of pure iron. The increase in carbon content adds to the mechanical strength though permeability is reduced. Hence this material is suitable for high speed machines and turbo alternates. The material, like pure iron is unsuitable for alternating flux.

*Silicon steel* : An alloy of steel and 3 to 4% silicon increases strength and decreases permeability resulting in considerable reduction in the eddy current losses. These alloys are therefore used both for A.C. and D.C. The material is used for making transformer poles armature poles and electrical machines.

*Manganese and nickel steels* : Steel is rendered non-magnetic by the addition of manganese and hence immensly suitable for situations where the material is required to use non-magnetic.

*Mu-metal* : It has high specific resistance and high permeability at low flux densities, resulting in small eddy current losses.

(2) *Magnetically hard materials* are used for making permanent magnets. The magnetic energy stored in a material is measured by the product of B (flux-density) and H (magnetising force). A material for a permanent magnet must have high value of BH product, high coercive force and strong magnetic reluctance. *Tungsten steel* (BH product of 250,000), *Chromium steel* (BH product of 225,000) and *Cobalt steel* (BH product of 1,000,000) are generally used. Tungsten steel and chromium steel require special care during heat treatment to avoid distortion and cracking. Cobalt steel is hard and strong, can be hot-forged, and can be machined after annealing. Other materials are as below :

*Alni.* (25%Ni, Al 15%). It can store large amount of magnetic energy on account of high BH value.

*Cunife* (Cu 60%, Ni 20%, Fe 20%). It is a copper nickel alloy of iron, a malleable, ductile and can be drawn into wire.

*Alcomax and Hycomax*: These are two iron, aluminium and cobalt alloys having directional (anisotropic) properties and are very suitable for making powerful magnets.

7.37.8 (c) *Electric Insulators or Dielectrics*: These are non-metallic materials of high specific resistance against the passage of electricity and so these are called non-conductors. These are used to prevent leakage of electricity from one conductor to another or to earth. The specific resistance of insulators decreases with the rise in temperature. The value of a material as non-conductor or insulator depends on its dielectric strength (G) in kilovolts per mm. of thickness, i.e. its ability to resist breakdown under high voltage.

The dielectric strength of a material is thus a measure of the material to stand high voltage. If the breakdown voltage is V and it occurs against thickness $t$, then dielectric strength $G = \frac{V}{t}$ kilovolts/mm. Dielectric strength of some of the important insulating materials is given below:

| Material | G kV/mm (average) |
|---|---|
| Asbestos ... | 3.5 |
| Bakelite ... | 22 |
| Ebonite ... | 25 |
| Glass ... | 8 |
| Mica ... | 100 |
| Porcelain ... | 15 |
| Slate* ... | 15 |
| Mineral Insulating Oil ... | 27 |

*Dielectric constant*. The dielectric constant of a material is defined as the rate of capacity of a condenser with dielectric is the material to capacity of the same conductor with vacuum or air as dielectric. The value is useful in the selection of the dielectric material for a condenser.

Very often, a material with good electrical properties is required because it does not possess the following properties, which may be termed as working properties :

(*i*) should be capable of withstanding high temperature.
(*ii*) should possess air resistance.
(*iii*) should have good mechanical strength.
(*iv*) should have good thermal conductivity.
(*v*) should be flexible.
(*vi*) should be resistant to corrosion.

### 7.37.9 *Solid Insulators.*

7.37.9.1 *Inorganic Insulators. Mica*—G=50-150. Mica splittings held together with cement or varnish are used for insulation.

*Asbestos*—G=3-4. Suitable for low voltage insulation. Used as covering for armature and field coils at high temperature. Sheets are used in lining and partitions in switch boxes or as shield for carbon arc.

*Porcelain*—G=16. Used as insulating supports for overhead lines and in making spark plugs. It is a high voltage insulator.

*Marble*—G=6. Used sometimes for switch boards.

*Slate*—G=8. Used as face plate for starters of electric machines.

7.31.9.2 *Organic Insulators. Ebonite*—G=50. Used as cover for resistance boxes.

*Paper*—G=4-10. Used for cable insulation and as covering for transformer conductors.

*Bitumen*—G=1-5. Used as filling for cable boxes and as insulation for low voltage mining cables.

*Bakelite*—G=5-15. Used for making electric fittings of lamp holders, switch covers, etc.

*Shellac*—G=11. Used for making insulating varnishes.

*Rubber*—It has good abrasion and water resisting properties but is damaged by heat. It had earlier been used for cables but its use is now being replaced by synthetics having rubber like properties.

*Wax*—It is used as an impregnating compound in condensers. It is water repellent and has high electrical resistance.

7.37.9.3 *Liquid Insulators.* These are used in switches, transformers and rheostats. *Paraffin oil* and *chlorinated diphenyl* are generally used for transformers and capacitors.

For easy flow the material should have low viscosity. The presence of moisture and dissolved gases adversely affects the dielectric strength and hence special precautions are to be taken in selecting the correct oil. These oils are now being replaced by synthetic liquid dielectrics like Pyranol which in addition to having the insulation property are non-inflammable and do not form emulsions with water.

7.37.9.4 *Transformer Oil.* It is used for transferring heat by convection from windings and core to cooling surfaces and also for maintaining the insulation of windings. The oil used is the mineral oil, which must be free from moisture as it reduces the insulating value of oil. A non-inflammable synthetic oil, such as, *chlorinated diphenyl* mixed with *trichlor-benzene* is used where fire hazards exist.

7.37.10 *Gaseous Insulators. Air* and *Nitrogen* are insulators. Pure and dry nitrogen at pressure has been used as insulating medium in power cables. For this purpose gas at 2 to 15 kg/cm$^2$ has been introduced as insulation.

Freon gas under pressure is used for high voltage X-ray machines.

7.37.11 *Fluorescent Lamp.* It is a mercury-vapour lamp in which calcium halophosphate is deposited in a thin layer on the inner surface of the tube. Practically a white light is produced. The tube has oxide-coated electrodes which are heated to favour starting on first switching on and then the current passes through both electrodes in series and rises those to incandescence. The life of fluorescent lamp is 3 times that of gas-filled lamp. The large area of the tube surface eliminates glare and the tube itself is much cooler than the gas-filled bulb. But its initial cost is high.

7.37.12 *Overhead Lines.* These are used for power transmission and distribution. Copper is usually used as conductors but in main transmission lines aluminium stranded over a steel core is used as conductor which is lighter and of high strength. Aluminium is cheaper than copper conductor and thereby reduces the number of towers, as it can be used on longer spans. Overhead lines are supported by pin-type porcelain insulators on wooden poles or steel towers but for high voltage suspension type insulators supported on steel towers are used.

7.37.13 *Underground High-tension Cables.* Each core of a three core high voltage cable consists of 7 copper wires of small diameters stranded together and covered with paper insulation. The three cores have a belt insulation of an impregnated paper. The space in between them is filled with hemp or jute. The insulated cable is then finally protected with a lead sheath. For very high voltages special hollow conductors, oil field, and single core cables are used. Underground cables are not liable to breakdown due to lightning and weather but it is very difficult to detect faults and repair them.

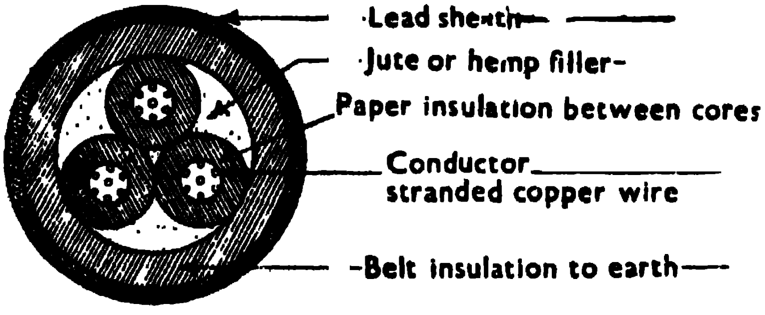

Lead sheath
Jute or hemp filler
Paper insulation between cores
Conductor stranded copper wire
Belt insulation to earth

Fig. 7.9 Underground cable

**7.37.14** *Lightning Conductor.* It is a system of metal conductors (copper, aluminium or iron) connected from the highest points of a building to earth for the easy and quick passage of lightning discharge so as to avoid any damage to the building. The conductors on the top of the building are sharp pointed radiating pieces so that the chances of a lightning stroke in the neighbourhood are greatly diminished.

## EXERCISE VII

### A. M. I. E. (I) Examination Questions

1. (a) Classify industrial fuels and discuss their suitability in various fields. (b) Compare water gas and producer gas. (May 1962)

2. (a) What are general properties of insulating materials ? Give two examples of an insulator with their uses and relative advantages in practice. (b) Explain the use of the following in electrical industry : (i) asbestos, (ii) mercury, (iii) resin, and (iv) oils. (May 1962)

3. (a) Describe briefly the principal ferromagnetic elements with their relative utility in industry, (b) Give some examples of non-magnetic alloys and explain the use of any two as an engineering material. (May 1962)

4. (a) Describe the properties of a good conducting material and mention some materials that can be used for high voltage transmission purposes with their relative advantages and disadvantages. (b) Write briefly about the metals used for lamp filaments and electric fuses. (May 1962)

5. What are refractory materials ? Detail a few types with their properties, manufacture and uses as engineering materials. (May 1962)

6. Write explanatory notes on any three of the following : (a) different types of belts and materials used for each, (b) jointing and packing materials, (c) different types of abrasive materials. (d) grinding pastes and their uses, (e) fibres. (May 1962 ; Nov. 1960)

7. (a) Discuss the properties of a good conducting material and mention some materials that can be used for high voltage transmission purposes with their relative advantages and disadvantages, (b) Write briefly about the metals used for lamp filaments and electric fuses. (May 1962)

8. (a) What are the two broad divisions into which all electrical materials could be divided ? How would you test the suitability of an insulator for a given voltage and situation ? (b) Discuss liquid and gaseous insulators mentioning when and where they are used. (Nov. 1961)

9. (a) Describe briefly the function of an electric conductor. Discuss aluminium as an alternative electric conductor to copper, showing its limitation and uses. (b) Explain briefly the uses of the following in the electrical industry : (i) lead, (ii) porcelain, (iii) paraffin and (iv) marble. (Nov. 1961)

10. What do you understand by the term 'underground electric power cable' ? What are its functions and uses ? What are the materials that are used in its construction and what point would you observe in the selection of each material and the safeguards you would make for its efficient working? (Nov. 1961)

11. (a) What is bitumen ? How is it obtained on a commercial scale ? (b) How would you test a sample of bitumen for its chief properties ? (c) Describe briefly its use in engineering construction. (May 1961, Nov. 1960)

12. Write short notes on (i) bauxite, (ii) silica, (iii) magnesite as refractory materials, mentioning their special properties and uses. (May 1961)

13. (a) Explain the term 'electric insulator'. What are its main functions ? Describe the chemical and physical properties. What do you understand by breakdown strength of an insulator ? Explain. (b) Describe (i) liquid insulators, (ii) gaseous insulators, mentioning where they are used. (May 1961)

14. (a) Explain briefly the functions of an 'electric conductor'. Discuss copper and aluminium as electric conductors and the scope of their use in electrical work and machinery. (b) Explain the uses of the following in electrical industry : (i) mercury, (ii) mica, (iii) rubber, (iv) porcelain. (May 1961)

15. Describe briefly the puposc of 'lightning conductors'. What points would you take into consideration in installing lightning conductors in a large and high building. (Nov. 1960 ; May 1959)

16. Mention some of the insulating materials generally used. Discuss the relative merits of any four of the following insulating materials : (a) rubber, (b) asbestos, (c) resin, (d) oils, (e) gas. (Nov. 1960)

17. Describe the various types of belts and materials used for each with their merits and demerits. (Nov. 1960, 1959)

18. Name some of the alloys used for electric resistances with their relative merits and demerits. (May 1960)

19. (a) Mention the various ferromagnetic alloys suitable for (i) permanent magnets, (ii) electrical machines. (b) What do you understand by 'non-magnetic alloys' ? Give examples of their uses in engineering works. (May 1960)

20. Explain the physical properties of fibrous materials and plastics used in the manufacture of gear, etc. Give two examples and discuss their merits and demerits. (May 1960)

21. (a) What metals and alloys are used for fuses ? Give a few examples for the same with their relative merits. (b) What materials are used for lamp filaments ? Comment on each. (Nov. 1959)

22. Write notes on (i) uses of asphalt and bitumen as materials of construction, (ii) gypsum plaster, (iii) cutback bitumen, (iv) bitumen and its uses. (May 1957 ; Nov. 1956)

23. Describe the properties expected of electrical contact materials. Discuss the suitability or otherwise of the following materials for electrical contacts : carbon, copper, palladium, silver, tungsten. (May 1957)

24. Write explanatory notes on : (i) oil suitable for transformers, (ii) high electrical resistance alloys. (May 1957)

25. (a) Explain the characteristic features of magnetically soft materials. What are the alloying elements used for making them ? Name any two types of such alloys and give their composition.

(b) What are oxide magnets ? (May 1957)

26. Discuss the requirements of bearing metals. Enumerate four types of bearing suitable for use under different conditions, giving reasons for their suitability. (May 1957)

27. Write short notes on : (a) asphalt and bitumen, (b) fire-bricks, (c) asbestos, (d) glass wools, (e) grinding wheel, (f) gypsum plaster, (g) plastic laminates, (h) suitability of rubber for belting, (i) heat resistant glasses, (j) part played by fillers in plastics. (May 1957 ; May, Nov. 1956)

28. What are the different varieties of solid fuels used ? Discuss their advantages and disadvantages. (Nov. 1956)

29. Describe the effects of copper, silicon and magnesium when alloyed with aluminium. Give examples of any three aluminium alloy castings and state their special uses. (Nov. 1956)

30. Write short notes on : (i) high alloy tool steel, (ii) defects in casting, (iii) processing of grey iron castings, (iv) stainless steels. (Nov. 1956)

31. Describe the structural changes that occur in steel in course of the following heat treatments : (i) hardening, (ii) tempering, (iii) annealing. Explain the meaning of the term 'curburizing' and describe the various processes of curburizing steel to impart desired properties. (Nov. 1956)

32. (a) Discuss the suitability or otherwise of the following as magnetic materials : (i) soft iron, (ii) cast iron, and (iii) low carbon steel.

(b) What materials are specified for electric fuses and why ? Give examples. (Nov. 1956)

33. Write short notes on : (i) ferromagnetic alloys, (ii) non-magnetic alloys, (iii) silicon electrical steels, (iv) filaments for lamps, (v) materials required for high tension cables. (Nov. 1956)

34. (a) Enumerate the general properties of thermal and electrical insulating materials.

(b) Discuss the suitability or otherwise of the following materials for insulating purposes : air, asbestos, porcelain, paraffin oil, rubber and cellulose. (Nov. 1956)

35. What are the functions of lubricants? Give an account of different kinds of lubricants commonly used, stating the factors influencing their selection. Why are cutting fluids used for machining operations? Suggest the types of fluids used for the following purposes (a) turning of ebonite, aluminium, yellow metal and mild steel rods in a central lathe, (b) deep drawing operations of mild steel and aluminium parts in a double acting mechanical press. (May 1956)

36. Write short notes on (i) Liquid fuels, (ii) Producer gas, (iii) Permutit process of softening water. (May 1956)

37. Give an account of the material commonly used for (i) lamp filament, (ii) heating elements for resistance heater and (iii) metals and alloys for fuses. (May 1956)

38. Name and draw up full specifications for at least three types of electrical conductors commonly used. (May 1956)

39. What are the different kinds of refractory materials commonly used? Give an account of their properties and use. (May 1956)

40. How does coal differ form coke? What are the requirements of coke for (i) iron blast furnace, (ii) Water-gas manufacture, (iii) steel foundry, and (iv) household ovens? Give the relative advantages of a gaseous fuel over liquid fuel and indicate the approximate composition and calorific values of (a) blast furnace gas, (b) coke oven gas and (c) water gas. Describe a modern process of making water gas. (Nov. 1955)

41. What should be the specific qualities of a lubricant? Point out how its choice is influenced by the pressure, speed, temperature and materials of construction of the machine parts and give suitable examples. (Nov. 1955)

## Engineering Services (I) Examination Questions

42. Write short notes on any five of the following : Bakelite, gypsum, water-cement ratio, asphalt, distemper, asbestos, masonite. (1962)

43. (a) Describe briefly with sketches the process of manufacturing glass. Name the different kinds of glasses and state their uses. (b) What are plastics and how are they moulded? (c) Name the different varieties of plastics with examples. What are their advantages. (1961)

44. Write short notes on any five of the following : cast steel, terra-cotta, mosaic floor, plywood, case-hardening, masonite sheets, distempers, asphalt and bitumen, varnish, dados. (1959)

## Other Examination Questions

45. (a) Define sheet glass and plate glass and give their uses.

(b) Distinguish between asphalt, pitch, coal tar and bitumen giving their characteristics and uses.

(c) What is glazing and how do you glaze a door leaf? What is ground glass and how do you grind it? What is the mixture for obscuring glass and the method of applying it.

46. What is asphalt? Mention some of its uses, noting the advantages and disadvantages in each case. Describe the methods of laying asphalt.

47. What are hard and soft waters? What is the hardness of water due to? Why should hard water be softened? Describe in brief one of the methods employed for removing the hardness of water.

48. Name the different fuels used and give their merits and demerits.

49. How is coal gas manufactured?

50. Give the names of fractions of petroleum and their uses.

# APPENDIX I

## WEIGHTS AND STRENGTHS OF MATERIALS

| Materials | Weight Tons/m$^3$ | Ultimate Strength kg/mm$^2$ | | | | Modulus of Elasticity E kg/mm$^2$ | Modulus of rigidity kg/mm$^2$ |
|---|---|---|---|---|---|---|---|
| | | Tension | Compre-ssion | | Shearing | | |
| Cast Iron ... | 7·2 | 13 | 63 to 79 | | 13 to 19 | 8,000 to 12,000 | 3,900 to 6,200 |
| Mild Steel ... | 7·9 | 39 to 55 | 38 | | 34 to 38 | 20,000 to 22,000 | 8,600 to 9,400 |
| Wrought Iron | 7·7 | 8.2 to 38 | 28 | | 16 to 32 | 19,000 to 20,000 | 7,800 to 8,600 |
| Copper (cast) | 8·8 | 15·7 | 5·5 | | 16 to 22 | 7,800 to 11,000 | 3,100 to 3,900 |
| „ (rolled) | 8·8 | 23·6 | — | | — | 8,600 to 11,700 | 3,100 to 4,400 |
| Brass (cast) | 8 | 8 to 15·7 | 8 to 9·5 | | 13 to 16 | 6,200 to 9,400 | 3,100 to 4,700 |
| Oak ... | 6·4 to 9·6 | 6·3 | 3·2 | along grains | ·64 | 7,800 to 700 | — |
| Pine (average) | 4 to 6·4 | 31 to 93 | 3·2 | | ·3 | 780 to 1,170 | — |
| Teak ... | 7·3 | 5 | 5·7 | | ·8 | 1,575 | — |
| Iron wood ... | 1·14 | 63 | 8 | | ·95 | 1,170 | — |
| Timber (average) | ·8 | 5·7 | 4·7 | | ·64 | 1,170 | — |
| Cement (set one week) | 1·44 | ·25 | 1·4 | | — | — | — |

## STRENGTH OF MASONRY TO RESIST CRUSHING

| Materials | Weight Tons/m$^3$ | Crushing weight kg/cm$^2$ |
|---|---|---|
| Brick work ... | 1·79 | 42 to 84 |
| Stone work ... | 1·79 to 1·83 | 56 |
| Granite ... | 2·72 | 700 to 1,400 |
| Lime stone ... | 2·1 to 2·6 | 490 to 630 |
| Sand stone ... | 2·1 | 350 to 700 |
| Concrete, ordinary ... | 1·9 | 28 to 49 |
| Concrete, cement ... | 2·2 | 119 |

# APPENDIX II

## BRITISH STANDARD SPECIFICATION FOR STRUCTURAL STEEL FOR BUILDINGS AND BRIDGES

The following abstract gives the important requirements. There are two grades of steel : A and B.

1. *Manufacture.*

A steel—made by Open Hearth Process but must not contain more than ·06% sulphur or phosphorus.

B steel- made by Open Hearth or Bessemer Process but must not contain more than ·06% of sulphur and ·08% of phosphorus. B steel is not for bridges, plates ¾" thick and above, and rivets.

2. *Tensile tests.*

For plates, rolled sections and flats -- Breaking stress 28 to 33 tons/sq. in., min. elongation 20% on 8" gauge length or 16% under ⅜" thick.

For round and square bars - Breaking stress 28 to 33 tons/sq. in , min. elongation 20% on gauge length 8 times diameter or 24% on 4 diameters in case of over 1" diameter.

For rivet bars– breaking stress 25 to 30 tons/sq. in., min. elongation 25% on 8 times diameter or 30% on 4 diameters.

3. *Bend tests.*

(a) Cold bend test Test piece must withstand, without facture, being doubled over until inner radius equals to 1½ time thickness ; test piece not less than 1½" wide, for smaller section piece cut from the bar as rolled is used.

(b) Test piece heated to a blood red heat and then quenched in water not hotter than 80° F. must stand test (a).

Rivets - Following bend tests are required for rivets :

(a) Shank of finished rivet is to bend cold double without facture.

(b) Finished rivet head must stand flattening hot without cracking until head diameter is 2½ times shank diameter.

4. *Margin.*

(a) *Specified length*-- Cut within a margin of 1" under or 1" over ; when cutting margin is not to be under the specified length, the margin within 2" over.

(b) *Exact length* - Cold-sawn or machined within a margin of ⅛".

(c) *Weights* 2½% over or under specified weights ; 5% over or under for specified min. or max. weights.

5. *Weight calculation.*

(a) Steel plate weighs 40·8 lbs./sq. ft. per inch of thickness.

(b) Rolled section or bar weighs 3·4 lbs./sq. in. per foot length.

# APPENDIX III

## APPROXIMATE RATES OF MATERIALS (Calcutta)

*($1^T$=1,016 tonnes, 1 md.=0·037 tonnes, 1 c.ft. =0·028 $m^3$, 1 sq.ft.=0·093 $m^2$)*

| | | Rs. | |
|---|---|---|---|
| 1. | Stone | 100% | cm. |
| 2. | Stone boulders | 90% | ,, |
| 3. | Stone metal 4 cm gauge | 110% | ,, |
| 4. | Stone chips 12mm to 18mm mesh | 140% | ,, |
| 5. | Ist class kiln brick at brick field | 85% | no. |
| 6. | 2nd class kiln brick at brick field | 82% | ,, |
| 7. | Picked Jhama bricks | 80% | ,, |
| 8. | Jhama bats | 60% | c.ft. |
| 9. | Ist class brick bats | 55% | ,, |
| 10. | Brick tiles (30cm × 30cm × 2·5 cm) | 60% | no. |
| 11. | Roofing tiles | 32% | ,, |
| 12. | Ridge tiles | 105% | ,, |
| 13. | Sutna lime 1 quintal | 100% | quint. |
| 14. | Shell lime | 2200% | ,, |
| 15. | Portland cement | 147 | tonnes |
| 16. | Fine sand | 14% | cm. |
| 17. | Medium sand | 19% | ,, |
| 18. | Coarse sand | 21% | ,, |
| 19. | Surki at site | 20% | ,, |
| 20. | Surki sifting at site | 16% | ,, |
| 21. | 12 mm sand plaster (1 : 2) | 1·7 | s.m. |
| 22. | 12 mm surki plaster (1 : 2) | 2·0 | ,, |
| 23. | 12 mm cement plaster (1 4) | 2·2 | ,, |
| 24. | Lime punning | 1·3 | ,, |
| 25. | Lime pointing (1 : 2) | 1·0 | ,, |
| 26. | Cement pointing (1 : 2) | 2·0 | ,, |
| 27. | Sand rubbing | ·7 | ,, |
| 28. | White washing 3 coats | 1·7 | ,, |
| 29. | Colour washing 2 coats | 2.3 | ,, |
| 30. | 2.5 cm Indian patent stone | 5·0 | ,, |
| 31. | Lime concrete (1 : 2 : 4) | 53% | cm. |
| 32. | Cement concrete (1 : 2 : 4) | 100% | ,, |
| 33. | Reinforced concrete (1 : 2 : 4) | 200% | ,, |
| 34. | Iron wood | 560 | cm. |
| 35. | Sal wood | 460 | ,, |
| 36. | Teak wood | 81 | ,, |
| 37. | 4 cm. sal planking | 18 | s.m |
| 38. | 4 cm. Teak ,, | 37 | ,, |
| 39. | Cast iron | 700 | M.T. |
| 40. | Mild steel | 800 | ,, |
| 41. | Lead | 2 | kg. |
| 42. | Copper (lump) | 8 | ,, |
| 43. | Tin (ingot) | 45 | ,, |
| 44. | Zinc (lump) | 3 | ,, |
| 45. | Brass (scrap) | 4 | ,, |
| 46. | Bronze (ingot) | 10 | ,, |
| 47. | 7·5 cm C. I. pipe | 7.5 | R.M |
| 48. | 10 cm C. I. pipe | 10 | ,, |
| 49. | Priming | ·5 | S.M. |
| 50. | Painting 2 coats | 1.6 | ,, |
| 51. | Copal varnish, 2 coats (New work) | 1.2 | ,, |
| 52. | Copal varnish (old work) | 1·8 | ,, |
| 53. | Oiling | ·30 | ,, |
| 54. | Turpenting | 15 | lit. |
| 55. | Coal tarring 2 coats | ·6 | S.M. |
| 56. | Coal-tar | .35 | lit. |
| 57. | Road tar | 350 | tonnes |
| 58. | Asphalt | 400 | ,, |
| 59. | Glue | 2½ | kg. |
| 60. | Emery cloth | 5 | doz. |
| 61. | Sand paper | 2 | ,, |
| 62. | Glass | 7·5 | S.M. |
| 63. | Asbestos corrugated sheets | 75 | ,, |
| 64. | Coir rope | 160 | quint. |
| 65. | Jute rope | 105 | ,, |
| 66. | Galvanized corrugated sheets | 92 | ,, |
| 67. | Nails | 2000 | ,, |
| 68. | Screws | 5 | gross |
| 69. | Bolts | 170 | quint. |
| 70. | Rivets | 195 | ,, |

# APPENDIX IV

## SUBJECTS OF STUDENTSHIP AND ASSOCIATED MEMBERSHIP EXAMINATIONS OF THE INSTITUTION OF ENGINEERS (India)

*Note*—Write to the Secretary, 8 Gokhale Road, Calcutta 20, for complete Rules, Syllabus and application forms.

*Studentship Examination*—Five papers only of 100 marks each.

1. English.
2. Mathematics I—Algebra; Trigonometry; Plain, Coordinate and Solid Geometry.
3. Mathematics II—Elementary Statics and Dynamics.
4. Physics—General, Heat, Light, Sound, Magnetism and Electricity.
5. Chemistry - Elementary Chemistry and Inorganic Chemistry.

*Associate Membership Examination*—Seventeen papers only of 100 marks each.

SECTION A. (Eight papers only to be taken. Compulsory for all seven branches of Engineering).

1. Mathematics I—Analytical Geometry and Differential Calculus.
2. Mathematics II—Integral Calculus, Differential Equations, Simple Vector Analysis and Graphics.
3. Applied Mechanics—Statics, Kinematics, Kinetics and Hydrostatics.
4. Principles and Applications of Electricity.
5. Heat, Light and Sound.
6. Engineering Drawing—Geometrical, Machine and Building Drawings.
7. Strength of Materials.
8. Elementary Surveying.

SECTION B. (Nine papers only to be taken. Seven compulsory and two optional).

CIVIL ENGINEERING.

*Compulsory*

1. Material and Construction 2. Theory and Design of Structures 3. Structural Eng. 4. Surveying and Geodesy 5. Hydraulics 6. Geology 7. Civil Eng. Design and Drawing.

*Optional* (any two)

8. Irrigation Eng. 9. Architecture 10. Soil Mechanics and Foundation Eng. 11. Railways 12. Agricultural Eng. 13. Public Health Eng. 14. Town Planning 15. Highway Eng. 16. Harbours and Docks 17. Thermodynamics and Heat Engines 18. Water Power Eng. 19 Production Technology and Industrial Administration.

*(For other branches of Engineering refer to Syllabus)*

SECTION C. The candidate will be assessed of the combined results of the report submitted by him giving an account of his Engineering training and experience, interview and essay writing (three hours paper) on specified subject within his professional experience. In lieu of above, a candidate may submit a thesis relating to research work in applied science actually carried out by him. Every candidate will be required to submit a report, an evidence of having had practical experience and a certificate in a prescribed form signed by the Engineer under whom the work was carried out.

# APPENDIX V

## A. M. I. E. (Ind.) EXAMINATION SYLLABUS
## ON
## ENGINEERING MATERIALS

*Common to all Candidates*

Outline of the manufacture of cast iron, wrought iron, mild steel, and other steels. Physical and mechanical properties of cast iron, wrought iron, and steel, and the effect of the common alloying elements on the mechanical properties of steel.

Physical and mechanical properties of the common non-ferrous metals and their alloys, viz., copper, aluminium, brass, bronze, light metals, white metals, Babbit metal, and their uses. Hard and soft solder.

Outlines of the manufacture and use of Portland cement. Use of bricks, lime, cement, mortars and concrete.

Seasoning of timbers; properties of good timber; defects and decay of timbers; preservation and principal engineering uses of timber. Ply-woods and their uses and other timber composition boards.

Fuels: solid, liquid and gaseous. Coal and coke, Crude oils and their functions, namely petrol, paraffin and diesel oil. Gaseous fuel, viz., town gas, coke oven gas, water gas and producer gas.

Refractory materials; different types, their properties and uses.

Water for engineering purposes; hard and soft water; treatment of water; boiler-feed water.

Corrosion of steel and iron and the protective coatings employed for prevention of corrosion.

*Special for Civil Engineering candidates*

Classification and characteristic qualities of building stores and road metals. Quarrying and blasting. Dressing of stones. Natural and artificial stones.

Bricks and tiles; preparation, burning in clamps and kilns; different types of kilns; characteristics of good bricks and tiles. Earthen and stone-ware products.

Building sands, their properties and source of supply. Preparation and uses of limes. Surki mortars. Hydraulic limes, their properties and uses. Ordinary and hydraulic mortars. Testing of limes, and cements. Composition, mixing and laying of plain and reinforced concrete. Plastering, lime punning, pointing, and white-washing. Gypsum and Plaster of Paris. Materials for paviors work; artificial stone, Terrazzo, etc.

Timber, its growth, selection and classification. Destructive agents, protective coating for timbers. Important varieties in use in India. Plastic materials used in building work.

Bitumen and bituminous surfacing. Paints and varnishes. Distemper, colour work. Glazing and papering materials. Putty, their composition and use. Road materials. Potable of water. Treatment of water for drinking purposes.

*Special for Electrical Engineering candidates*

Conductor materials: Properties and specifications of wire and cable materials. Alloys for use in electric resistances. Temperature effect on resistances of different materials. Carbon and graphite for brushes. Arc lamps and electric furnaces. Metals and alloys for fuses. Materials for lamp filaments.

Magnetic materials : Terms, definitions and classifications ; principal ferromagnetic elements and their alloys for magnetic uses ; soft iron, low carbon steel, cast iron, and cast steel ; magnetically soft magnet steel materials ; ferromagnetic alloys suitable for permanent magnets, electrical machines, instruments, relays, etc. Non-magnetic alloys.

Insulating Materials : General properties of insulating materials ; temperature rating of insulation and classification ; effect of moisture on insulation. Inorganic insulating materials as mica, asbestos, glass, porcelain, marble, slate, white clay, etc. Organic insulating materials as rubber, paper, fibre, wood, pitch, plastic, resins, varnish, etc. General descriptions and use of other types of insulation in use.

Insulating oils and liquids ; transformer oils, testing of insulating oils, Gas insulation.

*Special for Mechanical Engineering candidates*

Crystal structure and elementary metallography of iron and steel ; change of structure and physical properties with heat treatment. Meaning of annealing, normalising, hardening, tempering and seaking of steel. Effect of mechanical treatment.

Outline of manufacture, physical properties and uses of malleable castings and steel casting, cast steel ; case hardening of steel. Physical properties and uses of high alloy steels with special reference to high speed steel, and special alloy steels.

Lubricating materials, their classification, properties and uses.

Heat insulating materials and insulating materials for low temperature, their properties and uses. Jointing and packing materials.

Abrasive materials, their types and uses ; types of grinding wheels and their uses ; grinding pastes and their uses.

Materials for belting, cord and rope ; types of belts ; leather, cotton, hair, rubber and balata belts and their properties. Physical properties of fibrous materials and plastics used in the manufacture of gears and the like.

*Special for Chemical Engineering candidates*

Corrosion and chemical resistance. Factors influencing corrosion. Effect of corrosion on strength of construction materials. Chemical properties with special reference to the suitability of the following materials, viz., copper, nickel, chromium, Monel metal, lead, aluminium, tantalum, silver, gold, platinum, antimony, tin, cast iron, wrought iron, steel (all types including stainless steels), brass, bronze, silicon alloys, glass, silica wares, enamelled ware, stone ware, hard and soft rubber, wood, structural carbon and graphite.

Materials used for the construction of different parts of plants for the manufacture and storage of the following common chemicals, viz. acetic acid and fatty acids, hydrochloric, nitric and sulphuric acid ; ammonia ; caustic alkalies ; chlorine ; electrolytic cells ; salt and brine, fruit juices ; oils and fats of vegetable or animal ; mineral oils.

Materials used for armatures and measuring instruments as flow meter, gas meter, etc. in the above industrial plants.

Acid and Alkali resisting refractories, bricks, mortars and cements.

# APPENDIX VI

## EQUIVALENT METRIC UNITS AND CONVERSION FACTORS

| Sr. No. | Quantity | Unit | | Conversion Factors | |
|---|---|---|---|---|---|
| | | British | Metric | British to Metric | Metric to British |
| 1 | Length or Span | in | mm | 25·400 | 0·039 |
| | | in | cm | 2·540 | 0·394 |
| | | ft | metre (m) | 0·305 | 3·281 |
| | | yd | m | 0·914 | 1·094 |
| | | fur | km | 0·201 | 4·971 |
| | | mile | km | 1·609 | 0·621 |
| | | n. mile | i.n.mile | 1·001 | 0·999 |
| 2 | Area | in$^2$ | cm$^2$ | 6·451 | 0·155 |
| | | ft$^2$ | m$^2$ | 0·093 | 10·764 |
| | | yd$^2$ | m$^2$ | 0·836 | 1·196 |
| | | mile$^2$ | km$^2$ | 2·590 | 0·386 |
| | | acre | hectare (ha) | 0·405 | 2·471 |
| 3 | Volume | in$^3$ | cm$^3$ | 16·387 | 0·061 |
| | | ft$^3$ | m$^3$ | 0·028 | 35·315 |
| | | yd$^3$ | m$^3$ | 0·765 | 1·308 |
| | | acre ft | ham | 0·123 | 8·107 |
| 4 | Capacity | gal | litre (l) | 4·546 | 0·220 |
| 5 | Weight or Loading | oz | gram (g) | 28·350 | 0·035 |
| | | lb | kg | 0·454 | 2·205 |
| | | cwt | quintal (q) | 0·508 | 1·968 |
| | | ton (T) | tonne (t) | 1·016 | 0·984 |
| 6 | Linear Weight | lb/ft | kg/m | 1·488 | 0·672 |
| | | lb/yd | kg/m | 0·496 | 2·016 |
| | | T/ft | t/m | 3·333 | 0·300 |
| 7 | Density | lb/in$^3$ | g/cm$^3$ | 27·680 | 0·036 |
| | | lb/ft$^3$ | kg/m$^3$ | 16·019 | 0·062 |
| 8 | Moment of Inertia | in$^4$ | cm$^4$ | 41·623 | 0·024 |
| 9 | Section Modulus | in$^3$ | cm$^3$ | 16·387 | 0·061 |
| 10 | Radius of Gyration | in | cm | 2·540 | 0·394 |
| 11 | Bending Moment o Work | in-lb | kg-cm | 1·152 | 0·868 |
| | | ft-lb | kg-m | 0·138 | 7·233 |
| | | in-ton | kg-m | 25·803 | 0·039 |
| 12 | Stress or Pressure | lb/in$^2$ | kg/cm$^2$ | 0·070 | 14·223 |
| | | lb/ft$^2$ | kg/m$^2$ | 4·882 | 0·205 |
| | | ton/in$^2$ | kg/mm$^2$ | 1·575 | 0·635 |
| | | ton/ft$^2$ | t/m$^2$ | 10·937 | 0·091 |
| 13 | Temperature | °F | °C | $(F-32)\frac{5}{9}$ | $(C\times\frac{9}{5}+32)$ |
| 14 | Discharge | cusecs | m$^3$/s | 0·028 | 35·315 |
| 15 | Speed or Velocity | miles/h | km/h | 1·609 | 0·622 |
| | | ft/s | m/s | 0·305 | 3·281 |
| 16 | Acceleration | ft/s$^2$ | m/s$^2$ | 0·305 | 3·281 |
| 17 | Power | hp | kg-m/s | 76·040 | 0·013 |
| | | hp | kW | 0·746 | 1·341 |
| 18 | Heat | Btu | calories | 251·996 | 0·004 |
| 19 | Calorific value | Btu/lb | J/g | 2·326 | 0·430 |
| | | Btu/lb | cal/g | 0·556 | 1·800 |
| 20 | Specific heat | Btu/lb °F | J/g °C | 4·187 | 0·239 |
| | | Btu/lb °F | cal/g °C | 1·000 | 1·000 |

## UNIVERSITY OF BOMBAY

## F.E. (C.M.E.) Examination, 1962

## CIVIL ENGINEERING I (Engineering Materials)

(Maximum Marks—50)

*N.B.*—(1) Answer the two sections in *separate* books.
(2) Answer any *two* questions from each section.
(3) Figures in black to the right indicate marks for the full question.
(4) Quality of answers will be judged by their preciseness, freshness and technique of approach.

### SECTION I

**Marks**

1. (*a*) Suggest with valid reasons the types of cements you would recommend for carrying out the following works : **13**

   (i) Concrete pavement at busy road crossings.
   (ii) Concrete dam in a tropical country.
   (iii) Flooring of a cellar room subject to effects of sub-soil water.
   (iv) A furnace to withstand very high temperatures.

(*b*) Distinguish clearly the setting of cement from hardening of cement.

2. Name the three principal constituents of a blast furnace charge. In what form does it leave the blast furnace ? Give an account of the different blast furnace reactions, commencing from the feeding of the charge to the tapping of the metal. **13**

3. Give informative answers on any *four* of the following : **12**

(*a*) Ply woods and pressed woods, (*b*) Indian standard sand, (*c*) Rotary kiln, (*d*) Refractory clay, (*e*) Retarders and accelerators in cements, (*f*) Vibrated concrete.

4. Write a brief note of essential details on any *four* of the following : **12**

(*a*) Structural steel, (*b*) Centrifugal casting, (*c*) Heat treatment for steel, (*d*) Babbit alloys, (*e*) Muntz metal, (*f*) Sheet glass and plate glass.

### SECTION II

5. (*a*) State the geological classification of rocks. Name three varieties in each group. Mention their characteristic qualities and uses. **13**

(*b*) What do you consider are the modern materials of construction. Compare their relative merits with stones and bricks.

*Or*

(*a*) What are the essential features considered in deciding on the type of quarrying to be adopted. Outline briefly the methods adopted for obtaining : **13**

(i) Trap and basalt ; (ii) Granite ; (iii) Lime stones ;
(iv) Laterite.

(*b*) Show with proper sketches and proper reasons how a stone with laminated structure is placed in :

(i) a wall ; (ii) cornice ; and (iii) arch.

6. (*a*) State the principal varieties of limes, their characteristic properties and practical uses. 12

(*b*) Mention the different methods of obtaining lime from lime stones and explain with a neat sketch the working of a perpetual kiln.

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## UNIVERSITY OF ALIGARH

### B. Sc. (Engineering) EXAMINATION, 1962

### II Year

### CIVIL ENGINEERING (Building Materials)

Maximum Marks—50 Time—1½ Hours

*N.B*—(1) Answer all questions.

(2) All questions carry equal marks.

I. What requisite properties will you look for in a rock required for construction of an important public building in a large city and how will you test available samples to determine their suitability ? Describe two suitable varieties which are available within a reasonable distance from Aligarh.

II. (*a*) What are the characteristics of good bricks ? What tests are carried out for determining them ?

(*b*) Describe how brick earth is prepared.

III. (*a*) What do you understand by 'seasoning' of timber ? Explain why seasoning is essential.

(*b*) Describe with neat sketches a suitable plant for artificial seasoning of timber.

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## STATE COUNCIL FOR ENGINEERING AND TECHNICAL EDUCATION, GOVERNMENT OF WEST BENGAL

### SENIOR BOARD OF EXAMINATION AND SYLLABUS

### Licentiate Examination in Civil Engineering, August 1962

### Materials of Construction

TIME - 1½ HOURS. FULL MARKS - 50

*Answer three questions. All questions carry equal marks.*

1. (*a*) What is meant by "bulking of said" and how does it affect the concrete mix ?

(*b*) What is the difference between coarse aggregate and fine aggregate ? Why both are essential for a concrete mix ?

2. (*a*) Discuss the functions of the different constituents of a paint.

(*b*) Describe briefly how a paint is prepared.

3. (*a*) Enumerate briefly the timbers used in building works in the State of West Bengal with notes on their suitability.

(*b*) What is seasoning of timber and why is it done ?

4. (*a*) How many kinds of cement are there ? Enumerate them.

(*b*) Describe in brief the manufacture of any kind of cement.

5. Write notes on

(*a*) Texture of rock, (*b*) Enamel, (*c*) Mild steel, (*d*) Bitumen.

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## DEPARTMENT OF TECHNICAL EDUCATION, MADRAS STATE

### Diploma Examination in L.C.E. (N.R.)

APRIL 1962

TIME—ONE HOUR

*N.B.—Answer two questions. Neat sketches with assumed dimensions may be given wherever necessary.*

Marks

I. (*a*) What are the characteristics of (1) good building stones and (2) bricks ? 16

(*b*) Describe briefly the various stages in the manufacture of stock bricks.

II. Write short notes on 16

(*a*) Fire bricks. (*b*) Rapid hardening cement, (*c*) Surki mortar,

(*d*) Dry rot and wet rot.

III. (*a*) State the characteristics and principal uses of (1) Cast iron, (2) Wrought iron, and (3) Steel. 16

(*b*) What is varnish ? State the qualities of good varnish.

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## DEPARTMENT OF TECHNICAL EDUCATION, MAHARASHTRA STATE

### Annual Examination, 1962

### DIPLOMA COURSES IN CIVIL, MECH. & ELEC. ENGG.

**First Year.** Time Allowed—3 Hours. Marks—100.

### ENGINEERING MATERIALS

*Instructions* : (1) Answers to the two sections must be written in separate answer books.

(2) Attempt any *four* questions from Section I and *four* from Section II. Question No. 6 and 12 are compulsory.

(3) Illustrate your answers with neat sketches wherever necessary.

(4) Figures to the right indicate full marks.

### SECTION I

Marks

1. Describe the relative merits and demerits of clamp and kiln burning of bricks. 12

2. (*a*) What is an ore ? What are the three processes through which an ore must be passed for obtaining a metal from it ? 12

In what common forms is iron ore found ?

(*b*) Describe, with the help of a neat sketch, the manufacture of pig iron in a blast furnace.

3. What are the characteristics of heartwood and sapwood, and how do they affect their usefulness ? 12

How does the moisture present in wood affect its properties ? What is done to improve them ?

What is plywood ? From what is it made ? State its uses.

4. Distinguish between enamel, varnish and paint. Give the materials used in preparing any *one* of these three, mentioning the function of each material. 12

5. Write short notes on any *three* of the following : 12

(*a*) Terra-cotta, (*b*) Stainless steel, (*c*) Plaster of Paris.

(*d*) White glazed tiles, (*e*) Engineering uses of copper and of aluminium.

6. State briefly the technical reasons for any *seven* of the following : 14

(*a*) Burnt lime should be slaked as early as possible.

(*b*) In the drying field, raw bricks are laid on edge and a space kept between them.

(*c*) The sides of door and window frames which are to be in contact with masonry are painted with coal tar.

(*d*) Low-heat cement is used in very thick structures of concrete.

(*e*) Trees are often girdled before felling.

(*f*) Iron sheets used for roofing purpose are galvanised and corrugated.

(*g*) Gypsum is added while manufacturing cement.

(*h*) Wire-cut bricks have no frog.

(*i*) It is desirable to fell trees in winter rather than in summer.

## SECTION II

7. Answer any *two* of the following : 12

(*a*) What are the advantages of artificial stone ?

(*b*) Explain the following terms used in connection with building stones :

(*i*) Quarry sap, (*ii*) Line of least resistance, (*iii*) Natural bed.

(*c*) What is the action of the fuse in blasting ? Describe the action of blasting powder.

8. What is "hydraulicity" in lime ? State the different varieties of lime giving their composition, properties and uses. 12

9. What are the raw materials used in the manufacture of cement ? State, with reasons, the precautions to be taken in storing cement. What are the factors necessary for the proper setting of cement ? 12

10. Explain the following terms used in connection with mixing of concrete, stating the importance of each : 12

(*i*) Grading of aggregates, (*ii*) proportions of mixtures, and (*iii*) water-cement ratio.

11. For any *six* of the following items, write very briefly what the material is, stating its most important properties and engineering uses : 12

Mica, granite, porcelain, aluminium, surkhi, copper, pozzuolana, fire-clay.

12. Point out the distinction in the composition, properties, and use, in the case of any *four* of the following : 14

(*a*) Sheet glass and plain glass.
(*b*) Natural rubber and synthetic rubber.
(*c*) Plain concrete and reinforced concrete.
(*d*) Quick-setting cement and rapid-hardening cement.
(*e*) Thermosetting and thermoplastic plastics.
(*f*) Whitewash and distemper.

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## BOARD OF TECH. EDUCATION, M.P., BHOPAL

### Diploma Examination in Civil, Mech. & Elec. Engg.
### 1962

### FIRST YEAR

### Engineering (Building) Materials

Time—1½ Hours Max. Marks—50

**Note** : *Attempt only three questions. All questions carry equal marks.*

1. (*a*) Name three qualities of Building Stones with their chemical composition, strength and suitability for Buildings.

(*b*) What special qualities do you look for in stones used as road metal ?

2. (*a*) What is the difference between a clamp and kiln ? Illustrate by suitable sketches.

(*b*) Sketch a continuous kiln for lime burning.

3. Give brief specifications of :

(1) First class T.M. bricks.
(2) Lime concrete in foundation.
(3) Terrozo work or Dadoo Finish.
(4) Quality concrete for R.C. work.

4. How and where are the following building materials used ? What are their special advantages :

(*i*) Glass, (*ii*) Asbestos, (*iii*) Bitumen.

5. Give specifications for Teak wood required for making door and window shutters.

What are the modern methods of seasoning timber ? Describe them.

## BOARD OF TECH. EDUCATION, RAJASTHAN, JODHPUR

### Diploma Examination in Civil, Mech. & Elec. Engg.—1962

### Engineering Materials

Time : 3 hrs. Max. Marks : 100

*Answer any six questions. All questions carry equal marks.*

1. How is timber for engineering and building purposes classified ? Classify and give the principal uses of each of the following timbers :

(1) Deodar, (2) Chir, (3) Sal, (4) Teak, (5) Bamboo, (6) Neem, (7) Babool, (8) Mahogany.

2. What are the functions of the following in the preparation of paints :

(a) Base, (b) Vehicle, (c) Solvent, (d) Drier, (e) Colouring pigment.

Name the substances suitable for the purpose.

3. (a) What is Portland cement ? What precautions are usually taken in the storage of cement ?

(b) Describe the method of preparing cement concrete in the proportion of 1 : 1½ : 3, with local sand and brick ballast.

(c) What is curing ? What precautions are usually taken during curing ?

4. (a) What is plaster ? Why is plastering done ?

(b) Describe the method of plastering a newly constructed room with 1 : 6 cement plaster.

(c) What proportion of the lime mortar you would use for the following :

(i) Internal walls (ii) Ceiling.

5. (a) State with reasons the qualities to be sought for in good bricks.

(b) What is the most convenient size for burnt bricks ?
Give your reasons.

(c) What class of bricks would you specify for the following works :

(i) Brick on edge floor, (ii) Soling on roads, (iii) Brickwork in hutments, (iv) Archwork.

6. Name the stones suitable for the following work and give briefly their characteristics.

(a) Road metal, (b) Stone masonry, (c) Flooring, (d) Roofing.

7. What do you understand by fat lime and hydraulic lime ? Describe briefly the process of burning lime in a continuous kiln.

8. Write short notes on the following :

(a) Water cement ratio, (b) Asbestos, (c) Seasoning of Timber, (d) Roofing tiles.

## THE STATE COUNCIL FOR TECHNICAL EDUCATION, ASSAM

### Final Diploma Examination in Civil Engineering, 1962

**Subject**—DETAILS OF CONSTRUCTION.

1. Give a short description of and state the use in a building of following materials.

(a) Mortar, (b) Concrete, (c) Sand, (d) Cico.

2. What are the qualities of a first class brick ?

# INDEX

A

Abrasives, 281.
Absorption of water by stone, 9.
Acid test for stone, 9.
Adulteration of Portland cement, 109.
Agents which destroy stones, 11.
Aggregate for concrete, 130.
Air bricks, perforated, 63.
Air slaking of cement, 97.
Alkalies in clay for brick making, 33.
Alkaline silicates as a preservative for stone, 12.
Allotropic forms of iron, 216.
Alloys, 238.
Alumina in clay for brick making, 32 ; in fireclay, 63.
Aluminium, 235.
Analysis of brick earth, 34.
Portland cement, 97.
Angle iron, market forms and sections of, 222.
Annealing steel, 219.
Annual rings in trees, 163.
Anti-corrosion paint, 253.
Ants which destroy timber, protection against white ants, 174.
Artificial cement, 96 ; how manufactured ; 96 selenitic, 107.
Artificial hydraulic lime, 90.
Artificial stone, Ransome's, 25.
Asbestos, 280.
Ash, 87.
Asphalt, 274.
Asphaltic cement, 275.
Atmospheric influence on stones, 9.

B

Balk timber, 180.
Ballast used for railway, 27.
Bar iron, best, best best, 203.
Basalt, 21.
Bases for paints, 249.
Basic process, 206.
Bats, brick, 54.
Battens, 180.
Benzine, 274.
Bell-metal, 238.
Belts, 284.
Bessemer pig, 199 ; process of making steel, 205-213 ; Uses of steel; 227.
Birmingham wire gauge, 225.
Bitumen, 274.
Blister steel, 210.
Boiled linseed oil, 250.
Boiler feed water, 297.
Bolts and nuts, 225.
Brass, 238.
Breaking weights of briquettes, 103, 104, 105.
Brick earth, 32.
Brick making, 34.
Bricks, sizes of, 59.
Bridge-rail, 224.
Briquette of Portland cement, 104,105.
Bronze, 238.
Bulb angles and tees, 224.
Bulk of concrete produced of materials, 139, 140.
Bulking of sand, 111.
Burning bricks, 44 ; cement, 96 ; firebricks, 63 ; lime, 87 ; stoneware, 75 ; teera cotta, 76 ; tiles, 69.
Burnt clay as a substitute for sand, 113.

C

Calcareous clays, 34.
Calcination, 84.
Carbon, amount of, in cast iron, steel and wrought iron, 227 ; effect on iron, 222.
Carburising, 219.
Case-hardening, 219.
Cast iron, 200.
Cast nails, 287.
Cast steel, 210.
Casting in sand, 201.
Castings, examination of, 202.
Cellulose, 279.
Cement testing machine, 101.
Cementation, 205.
Cements, analysis of, 99.
Classification of limes, 85 ; hydraulic, 85.
Charring timber, 171.
Chemical analysis of brick earth, 34.
Clamps for burning bricks, 45.
Clasp nails, 288.
Clay, burnt, as a substitute for sand, 113.
Clays for brick making, calcareous, mild and strong, pure or foul, 33.
Clinkers, 97.
Clout nails, 288.
Coach screws, 290.
Coal, 276.
Coal gas, 276.
Coal tar, 278,
Cobalt blue, 249.
Coke, 277.
Cold blast, 197.
Combination mortar, 116.
Composition, of fireclay, 63 ; of limestones, 21 ; of sand stones, 21 ; of various alloys, 238 ; of solders, 241 ; of white paint to cover 100 sq. yds., 254.
Compression, resistance of bricks 59,60.
Concrete, 129 ; aggregate for, 130 ; ferro, 151 ; mixing 137 ; pre-stressed, 153 ; proportion of ingredients, 135 ; strength of, 144 ; mixers, 138.

Conductor materials, 300.
Continuous systems of kilns for lime burning, 89 ; cement burning, 97.
Conversion of timber, 176.
Converter used in Bessemer process, 206.
Copal varnishes, 260.
Copper, 234,
Cork products, 282.
Corrosion and preservation of iron and steel, 228.
Corrugated sheet iron, 225.
Corrugated tiles, 71.
Countersunk clouts, 288.
Creosote, 173.
Cupola furnace, 200.
Cupshakes in timber, 165.
Curing concrete, 147.
Cut nails, 287.

D

Defects in timber, 164 ; cupshakes, heartshakes, and starshakes, foxiness, rind-galls, twisted fibres and upsets, 164-65.
Defects in wrought iron, cold short, red or hot short, 205.
Destruction of timber by worms and insects, 174.
Dielectrics, 367.
Dog spikes, 288.
Dressing of stones, 19.
Druxiness, 168.
Drying brick, 44.

E

Earth for brick making, composition of, 32 ; practical classification of, 33 ; preparation of, 35.
Effect of carbon upon iron, 222.
Efflorescence on walls, 156.
Elastic limit of cast iron, wrought iron and steel, 228.
Electric insulators, 307.
Electroplating, 230.
Emery cloth, paper, 282.
Enamel paint, 252.
Encaustic tiles, 72.
Explosives, 15,17.

F

Factors of safety for cast iron, wrought iron and steel, 227.
Fat lime, 85.
Fatigue of metal, 218.
Feldspar in granite, 21.
Felt, 280.
Ferro concrete, 151.
Filter, 295, 296.
Fineness modulus, 133.
Fineness, Portland cement, 99,103.
Fire, preservation of timber from, 174.
Firebricks, 63.
Fireclay, 63.
Fixed oils, 250.
Flag stones, 23.
Flare kilns for burning lime, 89.
Fluorescent lamp, 309.
Flux used in melting iron, 197.
Forging, 218.
Foundry pig, 199.
Foxiness in timber, 165.
Free stone, 23.
Frog in hand-made bricks, 40.
Fuel, 275.

G

Galvanising as a means of preservation of iron, 229.
Gangue, 197.
Gasket, 282.
Gauge Birmingham wire, standard. wire, 225.
Gas Carbon, 277.
Glass, 267.
Glazier brads, 288.
Glazing clay wares, lead and salt, 76.
Glue, 271.
Gold leaf, 287.
Grading of aggregate, 133.
Granite, 21.
Granular limestone, 23.
Grey cast iron, 200.
Grinding clay for brick making, 35.
Grit, 23.
Ground glass, 269.
Grout, 119.
Gun metal, 238.
Gutta percha, 284.
Gypsum, 97.

H

Hacks for drying bricks, 44.
Haematite iron, ore, red and brown, 195.
Hardening and setting cement, 84.
Hardening and tempering steel, 219.
Hard water, 293.
Heat treatment of steel, 218.
Hert wood, 163.
Heat insulators, 299.
Hoffman's Kiln, 49.
Hollow bricks, 63.
Honeycombing, 167.
Hoop iron, 225.
Hornblende in syenite, 21.
Hume pipe, 298.
Hydraulicity of limes and cements, 85.

I

Igneous rocks, 2.
India rubber, vulcanised, 283.
I.S.S. for cement, 104.
Indigo, 249.
Ingredients in mix points, proporations of, 254.
Injurious effects of lead paint, 249.
Intermittent kilns for burning lime, 89.

Iron, 194.
Iron stone, clay, 195.
Invar, 213.
Ivory black, 249.

J

Joiners' brads, 288.

K

Kerosene, 274.
Kiln-burnt bricks, methods of distinguishing, 56.
Kilns for burning bricks, Bull's patents, 51 ; or burning cement 97 : for burning lime, 87.
Knotting, 279.

L

Lamp filaments, 302.
Lath, 282.
Laying asphalt, 275.
Laying concrete, 139.
Lead, 234.
Le Chatelier apparatus, 101.
Lightning conductor, 310.
Lime, artificial & hydraulic calcination of, 90 ; carbonate of, 84 ; caustic or quick, 84 ; classification of, 85 ; effect of, on clay for brick making, 32 ; hydrate of, 84 ; hydraulicity of, 84 ; kilns, classes of and operation of burning, 89 ; slaking of, 90 ; varieties of, 83 ; use of, 95.
Limestone, 84.
Linseed oil, 250.
Lubricating oil, 274.
Lubricants, 298.

M

Machine-moulding bricks, 42.
Magnetic iron ore, 195.
Magnetic materials, 305.
Mahogany, 186.
Malleable cast iron, 201.
Manufacture of cast iron, 201 ; cement, 96 ; lime, 87 steel, 205 ; wrought iron, 202.
Marble, 21.
Materials used in Electrical Eng.. 299.
Matrix for concrete, 129.
Medullary rays in timber, 163.
Metallography of iron & steel, 216.
Metals, 193-237.
Mica in granite, 21.
Mica products, 284.
Michaelis's cement-testing machine, 103.
Mixes in cement mortar for different items of work, 125.
Mixing mortar, 116.
Mixture of lime and cement for mortar, 119.
Mortar, 114-120.
Mottled cast iron, 201.
Mercury vapour lamp, 304.

N

Nails, 287.
Naptha, 257, 278.
Natural beds of stones, 8.
Non-Ferrous metals, 234.
Normalising, 219.
Nut oil, 250.
Nuts and bolts, 290.

O

Obscured glass, 269.
Oil, as a preservative for stone, 12.
Oil gas, 278.
Open hearth steel, 208.
Ores, iron, 194.
Overhead lines, 309.
Oxide of iron as a base for paints, 250.

P

Packing materials, 287.
Painting as a preservative for iron, 229 ; for timber, 173.
Paints and varnishes 248-266.
Papers for papering walls, 279. different classes of, 279, 280.
Paste, 280.
Petrol, 274.
Petrolium, 273.
Perforated bricks, 63, glass, 267.
Perpetual kiln for lime-burning, 89.
Phosphorus, effect of, on iron, 222.
Pig iron, 197.
Pigments, for coloured paints, 249.
Pit sand, 110.
Pitch, 278, coal tar and mineral tar, 278.
Planks, 180.
Plaster, use of, 120.
Plastics, 285.
Plumbers' solder, 241.
Plywood, 182.
Polish, French, 261.
Poppy oil, 250.
Portland cement, 97.
Pozzuolana mortar, 118.
Precautions in using mortar, 119.
Preparation of glue, 271.
Preservation of iron, 228.
Pre-stressed concrete, 153.
Producer gas, 278.
Protection of timber against worms and insects, 174.
Puddling, 203.
Pulp paper, 279.
Putty, 273.
Purification of water, 291.
Pyrites, iron, 195.

Q

Quantities of materials for 1 Cu m. of c. concrete, 136.
Quarrying, method of, 13.
Quick lime, 84.

Quick setting cement, 99, 104.

R

Ransome's artificial stone, 25.
Raw linseed oil, 250.
Recipes for furniture polish, 261.
Red bricks, 66.
Red cement, 145.
Refractories, 299.
Refractory clays, 63.
Remelting pig iron, 200.
Removing paint, 257.
Repainting old work, 257.
Resin, 228.
Resins as an ingredient of varnish, 217.
Rich or fat limes, 85.
Rind-Galls in timber, 271.
Rivets, 290.
Rocks, igneous, 2.
Roman cement, 97.
Ropes, 287.
Rose-nails, 288.
Rubber, India, 283.
Rust cement, 281.

S

Salt glazing, 76.
Sand, 109.
Sand stones, 21.
Sap wood, 163.
Sohist, 4.
Screw, 290.
Sea sand, 110.
Seasoning of timber, 168.
Sections of wrought iron and steel, market, 222.
Selenitic cement, 107.
Shear steel, 210.
Sheets, steel, 225.
Shelly limestone, 23.
Shuttering, 148.
Siemens' steel, 208.
Siemens Martin process, 208.
Size, 272.
Slag, 197.
Slate, 24.
Slating nails, 286.
Slop-moulding bricks, 38.
Slow-setting cements, 99,104.
Slump, 148.
Soft solder, 241.
Softening steel, 219.
Soft water, 293.
Solder, 240.
Solvents, 249.
Sound insulators, 299.
Spikes, dog, 288.
Spirit varnishes or lacquers, 261.
Standard wire gauge, 225.
Steel, 205.
Stoneware, 75
Strength of bricks, 61.
Strength of concrete, 144.
Stucco plaster, 122.

T

T iron, 224.
Tar, 276.
Teak, 188.
Terra cotta, 76.
Testing of lime, 91.
Tiles, 66.
Tile stones, 23.
Timber, defects in, 164.
Tin, 235.
Trap, 21.
Turpentine, 279.
Turpentine as a solvent, 250.
Turps, 250.
Twisted fibres in timber, 165.

U

Umber, burnt and raw, 249.
Underburnt bricks, 59.
Under ground cables, 309.
Upsets in timber, 165.

V

Varnish, 259,
Vehicles for paints, 249.
Verdigris as a colouring pigment, 249.
Vermilion as a pigment, 249.
Vicat's needle apparatus, 101.
Victoria stone, 25.
Voids in concrete, 131.
Volatile oils, 250.
Vulcanised India rubber, 235.

W

Water, 290.
Water-cement ratio, 146.
Water gas, 277.
Waxing, 263.
Welding, 279.
White ants, protection against, 174.
White lead, 249.
White pig, 199.
Whitewash, 128.
Wooden blocks, 182.
Worms, protection against, 174.
Worms which destroy stone, 12.

Y

Yello, colouring pigments, 249.
Yield 228.

Z

Zinc, 235.
Zinc paint, 249.